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MODERN RESEARCH IN THE METALLURGY OF IRON.*

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OF all the seventy or eighty elements of which the materials of the universe, as revealed and proved by the spectroscope and chemical research, are found to be made, there is none so interesting to mankind as iron. With iron man has carved his destiny upon the face of the eternal ages. With sword, scimitar, spear and javelin, he began his conquering march. Later the plowshare and the pen appeared upon the stage of action and proclaimed themselves mightier than the sword. In the present strenuous day we are more than ever in a position to realize that iron is indeed the king of the material elements, with powers potential to guide and to lead the destinies of our race. Let us, then, review briefly the characteristics and capacities of this most wonderful protean element.

Familiarity breeds contempt, and those things which have been given us in abundance are treated with but scant respect. A heap of scrap-iron excites the contemptuous survey of the average man, whereas a small pile of gold behind an iron grating awakens an answering glitter in his eyes. But let us take pause for a

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moment. Considered from the standpoint of a metal and not for what it represents, gold is one of the most useless, albeit one of the most stable, of elements. Unattacked by nature through corrosion and oxidation, its comparative rarity, and perhaps its great beauty, constitute its principal claims as a metal. As a medium of exchange, gold is ever subject to fluctuating value as measured by the commodity or necessity it buys, and in earlier ages it has been subject to the fraud and to the debasement of those whose purposes it has been made to serve. In fact, although among the most permanent and stable of elements, gold has had little or no practical purpose in history except for personal adornment and as a medium of sentiment. Man could have gotten along without this precious metal and easily found a substitute for it. But how about iron? Let us briefly review what this metal has been the means of doing in the development of mankind, and, to keep true to our subject, what man's research in connection with this wonderful element has brought about.

It is related that when Richard II of England and Saladin, the great leader of the Moslem hosts, met in the early days where modern history begins, the champion of the west displayed a broadsword so strong that with it he was able to cleave a thick bar of iron. To this accomplishment the hero of the east replied by a stroke of a scimitar so keen that it sheared in twain a thick cushion stuffed with down. And so the extraordinary characteristics and possibilities of this metal have been played upon by man throughout the ages, from the most ancient to the most modern days. Both for strength and delicacy, what element designed by nature for the use of man has equalled iron?

But it is not in the tale of war or even of agriculture, art or letters, or even in its protean strength that this element has signalized its highest or its best use to mankind. From the delicacy of the hair spring of a lady's watch to the high-powered shaft and gun of a modern battleship, its range exhibits itself. From a cambric needle to a modern steel railroad rail is a far cry, but consider for a few moments what fields of research and endeavor have been opened up through the simple fundamental fact that soft iron is possessed of the power of exhibiting evanescent or temporary magnetism, while steel, the product of iron, conceals within itself the power of developing permanent or lasting magnetic properties. With a tiny, delicately balanced magnetic needle,

the early explorers opened up new worlds and continents; but it has been in the development of this magnetic property in the hands, first, of great scientists like Michael Faraday and, later, in those of the modern research student, that vastly greater worlds of scientific possibility have been explored and opened up to the lasting glory and benefit of the race. Every electrical instrument, every dynamo, motor, telephone or telegraph, including the modern wireless systems, depend entirely upon the properties of magnetism.

With its wonderful properties, therefore, and with its development growing apace, it is not astonishing that the element, iron, and its derivative, steel, should have been not only one of the earliest but one of the most persistent subjects of research.

The terms "iron" and "steel" are more or less vaguely differentiated, both by the layman and the professional metallurgist. Therefore, before proceeding further with our subject, it will be well if we understand, at least for the time being, just what we mean by these terms. There is a difference of opinion even among scientific men who have spent their lives in metallurgical research in regard to the exact definitions of the words "iron" and "steel." For our present purposes, however, let us take refuge in the common definitions as given in the dictionary, to which the layman of the world turns for information in regard to the meaning of the words which he employs. Webster's New Century Dictionary defines iron very simply as the most common and useful of the metals, and this same authority defines steel as refined iron combined with carbon. These definitions, which the writer accepts as true ones both from the standpoints of common usage and scientific interpretation, lead us naturally to the introduction of the subject under discussion in this paper, namely, modern research in the metallurgy of iron and steel. Before proceeding further into our subject, however, it is necessary to pause long enough to point out that research work can be classified very readily under separate headings. In ancient time research work into the capabilities of metallic iron was confined to the wonderful old smiths and artisans who produced, by the crudest means, examples of hardened steel whose qualities and character challenge the admiration of and, perhaps, even to some extent defy imitation by modern methods. All that the ancient artisan found out he usually kept to himself, or at

best he divulged his secrets only to his own apprentices and immediate disciples. With this form of research work we are not at present concerned. Modern scientific methods, however, can be considered under two main heads which I shall distinguish as plant and laboratory research. When Bessemer and his contemporaries, some fifty to sixty years ago, conceived the idea of refining iron on the large scale of operation by the pneumatic process—that is to say, by blowing air under pressure through a mass of molten metal—the experimental work could only be done upon the plant scale of investigation, with its attendant difficulties, enormous cost and danger. It has been, comparatively speaking, only within the last two decades that laboratory research in iron metallurgy has come to the assistance of the clumsier and more cumbersome method of plant scale investigation. It must at once become apparent that the most useful and the richest field is opened up where the laboratory investigator and the man who knows how to work enormous masses of metal at high temperatures join hands with a common purpose in view.

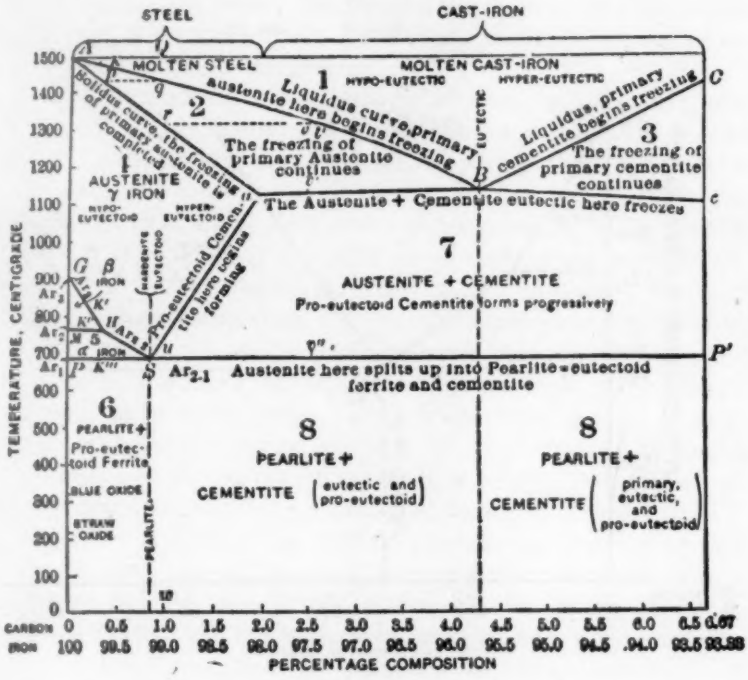
As has already been suggested, one of the extraordinary characteristics of iron depends upon the fact that it possesses an affinity for the element carbon, and combines with small quantities of this element in such a manner as to completely change its inherent characteristics. In other words, iron dissolves and seeks to dissolve in itself carbon, and it is this tendency which bears within itself potentialities of a most wonderful and extraordinary nature. I can best introduce this particular phase of the subject by making reference to what is known to metallurgists as the *Carbon-iron diagram*, which has been accurately worked out by research students and which as completely maps the possibilities lying within the combination of cast iron on the one hand and pure iron and high carbon steels on the other, as the geographical map is capable of placing before us a broad purview of the whole or a portion of the earth's surface. This diagram has been worked out with the aid of the microscope and by modern pyrometric methods for measuring high temperatures, even as high as those known to exist in the sun, with great accuracy, both lines of research representing to a great extent a very modern development.

The carbon-iron diagram, as worked out in its entirety by

our own distinguished metallurgist, Henry M. Howe, is shown in Fig. 1. For the sake of simplicity a detail of a portion of the diagram is shown in Fig. 2.

I cannot attempt, in the limited time allotted to me, to elucidate all that the iron-carbon diagram has opened up to us, but must content myself with pointing out some interesting and salient features.

FIG. 1.

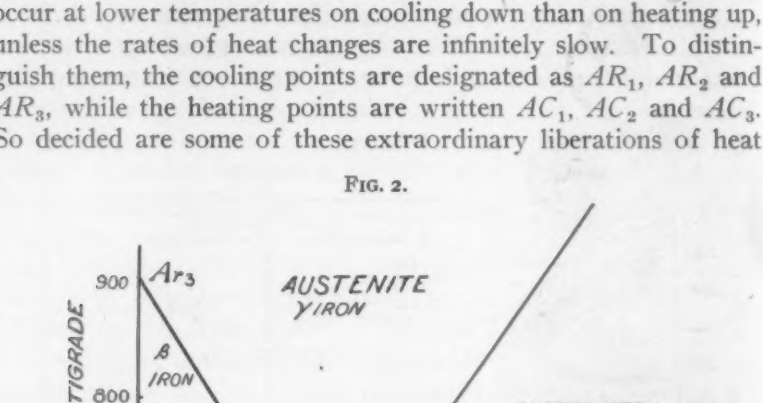


The carbon-iron diagram (Howe).

It has been known for a long time that if we heat iron or steel gradually until we arrive at the melting point of the metal, the rate of heating does not proceed uniformly. In the same way, if we start with iron or steel in the molten condition and cool it gradually, in both cases, at certain fixed temperatures, retardations in heat changes occur. These points are known as "critical points" or "critical temperatures." They are unquestionably caused by physical changes whereby heat is liberated at the critical

points on cooling, or absorbed on heating. The three principal critical points which have been mapped are designated as A_1, A_2 and A_3. On account of molecular inertia or lag, these changes occur at lower temperatures on cooling down than on heating up, unless the rates of heat changes are infinitely slow. To distinguish them, the cooling points are designated as AR_1, AR_2 and AR_3, while the heating points are written AC_1, AC_2 and AC_3. So decided are some of these extraordinary liberations of heat

FIG. 2.



Detail of iron-carbon diagram.

that the temperature of the cooling mass may be even raised slightly, and, when the observer is in the dark, a sudden glowing may be seen. This phenomenon is termed recalescence, and has been made the subject of much research work and inquiry, a number of theories having been advanced to explain what takes place. The commonly accepted explanation is that iron exists in at least two, and possibly three, allotropic modifications, and that the heat which is given off or absorbed, as the case may be, represents the energy of atomic rearrangements which are taking place.

A very familiar example of an element which exists in several allotropic modifications, without changing its chemical constitution, is that of ordinary carbon. One allotropic form of this element is the diamond, while a piece of charcoal or a piece of graphite may represent two other allotropic modifications. In the same way, then, we are to understand that iron is capable of existing in different modifications, and that these interesting critical points are simply the temperature points at which these changes of form take place. According to the best authorities, as described by G. K. Burgess:[1]

"The question of the allotropy of iron, in spite of a vast amount of experimental work and perhaps an even greater amount of theorizing, is not yet settled. That there is a definite transformation in iron near 900°, the A_3 point, is generally recognized, as well as the fact that the temperature of this transformation is lowered by the addition of carbon and metallic elements. On heating the transformation Ac_3 is always found at a higher temperature than the transformation Ar_3 on cooling. Whether the A_3 transformation is sharp, like the melting-point of a pure substance, or extends over a considerable range of temperatures, embracing perhaps as a lower limit the A_2 change, appears to be still an open question for pure iron. The nature and identity of the A_2 transformation, it would appear from recent publications, has not yet been satisfactorily settled."

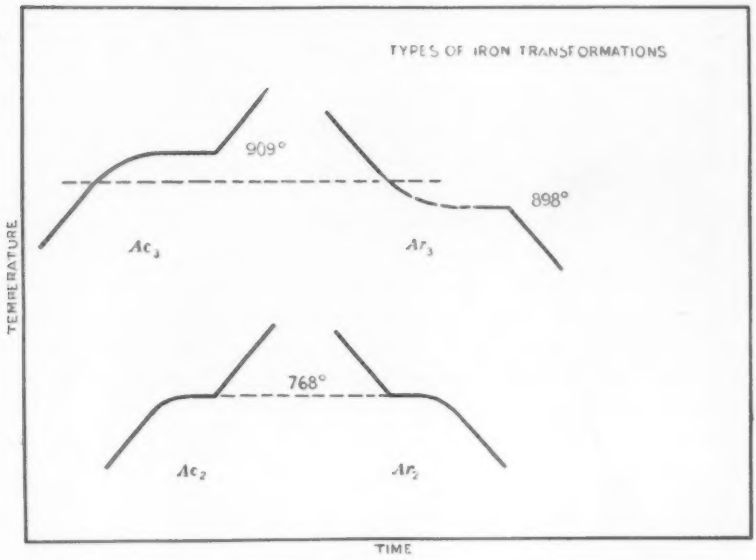
It seems at least to be generally conceded that the critical points A_3 and A_2 divide iron into separate allotropic forms. These are defined as α, β and γ iron. γ iron exists above A_3 and α iron below A_2. The A_2 point may or may not be another transition point so that at the present time the existence of a β modification between A_2 and A_3 is in debate. The subject is too involved for discussion in this paper, but in any event it is certain that an interesting change or transformation takes place at the point A_2 which is associated mainly with the loss of the interesting property of magnetism which α iron exhibits. If chemically pure iron is the material under investigation, these critical points can be simply plotted on a diagrammatic curve, as published by G. K. Burgess and his co-workers and shown here in Fig. 3. When steels of varying composition are under consideration,

[1] Critical Ranges A_2 and A_3 of Pure Iron. G. K. Burgess and J. J. Crowe; Scientific Paper, U. S. Bureau of Standards 213, p. 316.

however, these critical points, as shown on the iron-carbon diagram, indicate all sorts of interesting changes which may take place.

That branch of metallurgy which treats of the constitution and structure of metals and alloys is known as metallography, and, with the aid of the microscope in the hands of research students, a number of different definite constituents of iron and steel have been distinguished, studied and named. Among these constituents it is necessary to define the following.

FIG. 3.



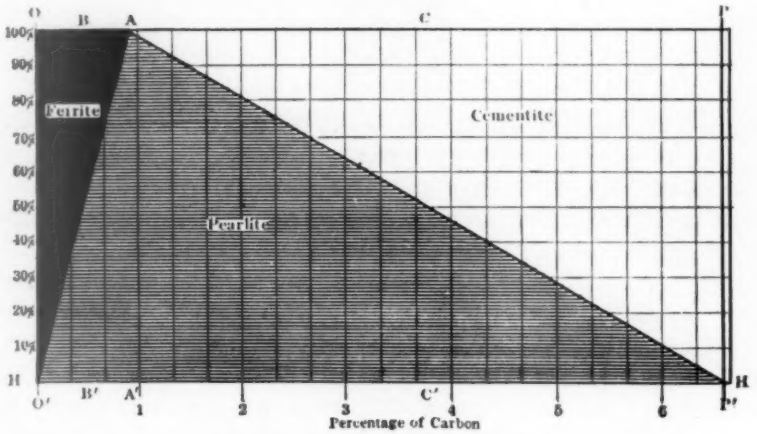
Ferrite is the name applied to pure iron, and is employed to designate that part of iron or steel which is not in combination with carbon but which may have crystallized out from a solidifying mass, in the practically pure condition. Ferrite is easily recognized under the microscope by its characteristic grain.

Cementite is the name given to a carbide of iron having a definite formula (Fe_3C). It represents a normal carbide of iron which also crystallizes out as a molten mass of carbon steel solidifies.

If a solution of common salt in water, such as sea water, is cooled at certain temperatures, depending upon the percentage of salt present, either salt or ice commences to crystallize out.

and this action continues until the remaining solution, called the "mother liquor," has a definite composition, when it finally freezes out together in a mixture of minute plates of alternate ice and salt which is scientifically known as cryo-hydrate. Whenever a similar action takes place in the cooling and freezing of molten alloys, the terms "mother metal" or "magma" and "eutectic" are substituted for mother liquor and cryo-hydrate, respectively. An interesting constituent which is always found in ordinary carbon steels which have been cooled in the usual way

FIG. 4.



Constituents of annealed carbon steels.

is a eutectoid or eutectic-like substance consisting of a mixture of alternate minute plates of ferrite and cementite crystallized out. When a sample of the solidified steel is highly polished and slightly etched with an acid body and examined under the microscope, this constituent appears as a pearly iridescent substance and is known to metallurgists by the appropriate name of *pearlite*. These separate substances, which we have defined as ferrite, cementite and pearlite, are the three most important constituents of steel which are ordinarily considered. The amount of pearlite, ferrite or cementite, in different compounds of iron and carbon, as shown graphically by O. M. Becker,[2] a well-known authority, is given in Fig. 4. The line of abscissæ here represents the amount of carbon present and the ordinates the amount of

[2] High Speed Steel; Becker. McGraw-Hill Book Co., New York, 1910, p. 26.

the three constituents. In addition to these constituents, however, the research student of iron and steel has to take into consideration a number of other important constituents which have been for the most part named after distinguished research metallurgists. Thus we have to consider such constituents as austenite, martensite, troostite, sorbite, and osmondite.

In a general way it may be explained that some or all of these carbon-iron constituents are formed when steel which has been heated to some temperature above the critical point A_3, but below the melting-point, is suddenly quenched in water or oil and then perhaps slowly reheated or tempered. Such action is now known in a general way as "heat treatment." For instance, if a carbon steel containing about 1.5 per cent. of carbon is heated to 1100° C. and then suddenly plunged into cold water, a so-called solid solution of iron carbide (cementite) in pure iron (ferrite) is suddenly locked or fixed in the structure of the steel. This is the austenite of modern metallurgical research. If such a metal is subsequently annealed by prolonged heating, the austenite breaks down again into the softer pearlitic structure. This is an important point and should be borne in mind in order to make clear what we shall discuss later. Martensite is used to designate a transition from between austenite on the one hand and ferrite and cementite (pearlite) on the other, and is a varying combination of the three constituents. Troostite, sorbite, and osmondite we need not take time here to define in detail. In general, they are terms used to designate transition forms between the constituents already described. Pure iron, of course, consists only of ferrite and contains none of these various carbon constituents.

All this scientific nomenclature is of special interest to the immediate purpose of this paper only to the extent that it serves to illustrate what modern research has done and is now doing to explain and elucidate the extraordinary characteristics of iron and steel. The old-fashioned smith or artisan quenched and tempered his steels and was guided to his result by watching the characteristic colors imparted to his metal by the changes from one constituent to another. The modern metallurgist no longer trusts his eyes but is guided along his path of development by the aid of the microscope and pyrometer. As a distinguished authority has stated:[3]

[3] Becker, *loc. cit.*, p. 7.

"For at least a thousand years, and probably for several thousand, there had been no single important advance, no one striking development, in the nature and characteristics of steel, in respect to metal-cutting qualities at any rate. The property of becoming hard, possessed in common by all steels, and distinguishing them from ordinary iron, is due to the presence of carbon diffused throughout the mass of the metal. How the presence of the particles of carbon brings about the virtue of hardening is yet a matter of discussion.

"Modern steel making is a fact only because the science of chemistry, itself scarcely a century and a half old, has made it possible to understand that there is an affinity of certain elements for certain others and that under given conditions exactly the same combinations can be expected in chemical compounds and alloys. The prehistoric steel makers had no idea that in firing iron with certain fuels they were carbonizing it, actually forming of the iron and fuel a new substance which contained besides iron the same element which in one form constitutes charcoal, in another graphite, and in a third diamond. That, however, is exactly what they did."

The salient fact which makes research work in the field of iron and steel metallurgy so fascinating and valuable is the rich possibilities involved in its exploitation. The writer imagines, without knowing from personal experience, that the fascination of the pursuit of the study of music to a real musician or composer must reside in the almost infinite possibilities which lie within combinations of harmonies and musical themes. To a very considerable extent the modern metallurgist is a composer who is playing on a combination of almost limitless possibilities. If there is any one reason more than another which proves this statement true, it depends upon these two facts: First, because either by an accident of nature or by design the two elements, iron and carbon, possess affinities which cause them to combine in a succession of almost harmonic possibilities; and, second, because iron also has the power of linking up or combining with or dissolving in itself nearly all of the other material elements in such a manner and with such a character that the most minute quantities of these elements or combinations of them produce differences in the resulting metal or alloy, of the most profound and important nature. Allow me to dwell briefly on this idea.

It is an interesting fact that out of the seventy to eighty elements which comprise, as it were, the building blocks of the material universe, only about twelve or fourteen are commonly used either by nature or by man. All the others are what may be generally classed as rare elements, even the names of which sound strange and unfamiliar to the ears of men of ordinary education. These rare or rarer elements seem to comprise nature's scrap-heap, into which scientific man is painstakingly digging and delving in the effort to gain something from it for his purpose. What the chemist and physicist has done with this scrap-heap is prominently before us in these days, for he has discovered and introduced to us such wonder elements as radium and thorium, and now he is finding a use for the extraordinary element selenium, which changes its electrical conductivity under the influence of light and other sources of radiant energy. I would not like to prophesy as to the wonders man may accomplish in the future, due to this unusual and unique property possessed by the element selenium. But to return to our subject, I wish to point out that the research metallurgist has not been idle in poking about in nature's scrap-heap for elements to combine with iron and thus increase the wonder-working properties of this already wonderful metal.

Let us consider the names of some of the more prominent of these rare elements which research has introduced into the metallurgy of iron and steel, and review briefly what has been accomplished by their aid. Chromium, tungsten, vanadium, molybdenum, titanium, cobalt, tantalum—these rare elements have now their well-recognized place in the commercial exploitation of alloy steels. Steels containing, comparatively speaking, only very small quantities of these elements are made into tools which possess so-called self-hardening properties and are known as "high-speed" tools. With such tools as these, enormous chips can be cut at high speed in heavy lathe and machine work. In many cases the tools can be used without oil and the chip and tool can safely be allowed to run almost red hot without damage to tool or work. Think of the economies in labor and time introduced by such a wonderful property as this. How can the influence thus exerted by these rare elements be explained? Becker tells us:[4]

[4] O. M. Becker, *loc. cit.*, p. 6.

"Carbon steel, as heretofore used in tools, no matter how well hardened, has not enough toughness and hardness to withstand the rubbing of the chip for any considerable length of time, even when not run fast enough to affect the temper. The tool therefore dulls; and this dulling proceeds in a sort of geometrical ratio as the cutting speed increases, being augmented by the drawing of the temper which accompanies rapid cutting. The speed in all metal-cutting operations has therefore had to be comparatively slow, no matter how powerful might be the machines in use. Thirty feet of chip per minute, as any machinist knows, has been considered rather good work; while fifty feet per minute has been very unusual. Under ordinary circumstances the management of a shop was pretty well satisfied if the machine tools could maintain an average speed of twenty to twenty-five feet per minute.

"Such deliberation, necessary though it has been, is depressing in this era. A creeping mass of metal turning leisurely round and round or moving back and forth, as has been customary in the average shop, is quite out of harmony with the modern spirit of expedition and hurry. But while a few dreamed of the possibilities of cutting metal, some time in the future, with something of the vim with which wood can be cut; and while machines had been developed so tremendously as to leave scarcely anything to be desired in that respect; nevertheless the ultimate limit seemed to have been reached.

"But it had not."

In the review of the special constituents of steel, it was pointed out that certain extraordinary changes in the character of ordinary carbon steels take place, due to heat treatment through and about certain well defined critical points. The carbon-iron diagram shows that the hard constituents of steel are austenite and martensite, but if steels in which these constituents have been fixed by quenching and tempering are then annealed by high or prolonged heating, these constituents break down into the softer pearlite. Becker accounts for the influence of these rare elements as follows:[5]

"Tungsten acts first as a strong obstruction to all the steps in the change from austenite to pearlite, so that if we have 7 per cent. or more of tungsten present, a moderately rapid cooling,

[5] O. M. Becker, *loc. cit.*, p. 40.

even such as allowing the bar to cool in the air, will prevent the change to pearlite. Indeed, when tungsten steels are to be annealed and the pearlite stage produced, it is necessary that the cooling shall be very slow indeed, occupying several times as long as the annealing of normal carbon steels.

"Tungsten acts secondly as a powerful fixing agent for martensite. It has been already shown that martensite is not stable in normal carbon steel even after it has been induced there by hardening, unless the metal be kept cool. Warming it up to the so-called temper heats changes the martensite over to troostite,

FIG. 5.

The vanadium mines at Minas Ragra, near the backbone of the Andes.

and if the heating be continued, even the effective hardness of troostite is lost long before the steel reaches a red heat. The presence of 7 per cent. or more of tungsten, however, increases the stability of martensite so much that the steel may be heated well above the tempering heats before the martensite even begins to break down into troostite or pearlite.

"Red hardness is the quality of hardness when at a red heat, and tungsten imparts this to steel under certain conditions, for a time at least. That is to say, we may cut with a tungsten steel at

so rapid a rate that the point of a tool will reach that temperature where it almost begins to glow in a dark room, and still the steel will retain its hardness for many hours."

Vanadium, and vanadium and chromium together, are used to produce the wonderfully tough, anti-fatigue steels which are gradually supplanting all types of ordinary carbon steels in cases where very strenuous service is to be encountered, such, for instance, as in automobile and locomotive parts, and for springs of

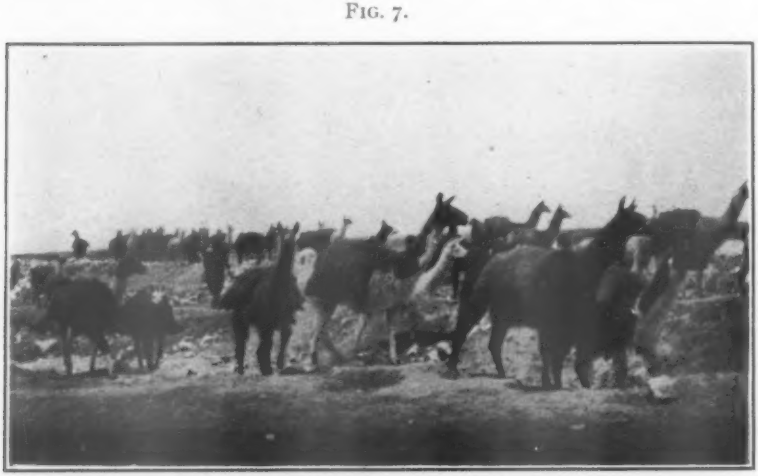
FIG. 6.

The Meigs railroad leading up to the vanadium mines.

all sorts, which are more or less continually in motion. The extraordinary thing about vanadium is that less than two-tenths of one per cent. of this element is all that is usually necessary to confer upon steel this wonderful new property of resistance to fatigue. It is fortunate that this is so, for the principal source of vanadium is a vanadium sulphide ore which is painfully grubbed out of the sides and peaks of the Peruvian Andes, about sixteen thousand feet above the level of the sea. Fig. 5 shows the vanadium mines at Minas Ragra near the backbone of the Andes. Fig. 6 shows the Meigs railroad leading part way

up, constructed by Colonel Meigs, the well-known American engineer. The ore is carried in bags on the backs of llamas to the sea coast, and eventually landed in the Pittsburgh district, where it is made into ferro-vanadium, an alloy of iron and vanadium, which, in turn, is used by the alloy steel makers in the manufacture of their special compositions. It is a curious thought that this rare material is found only in these apparently inaccessible places and then is carried upon the backs of llamas (Fig. 7), representing the most primitive form of transportation used in commerce, to find its special service in the manufacture of the

FIG. 7.



A group of llamas ready to transport the vanadium ore from the mines to the railroad.

most finished and developed means of transportation such as the modern locomotive, automobile and aëroplane. Fig. 8 shows a vanadium steel saw which was kept coiled for four years and when unstrapped came out almost straight.

Titanium finds its special use as a deoxidizer or purifier of molten steel, and it has been claimed that its use in small quantities produces great improvement in steel rails. The use of any element which claims to safeguard life by reducing accidents due to rail breakage must be watched with interest. Cobalt is the latest recruit to be enlisted in the making of high-speed steels possessing especially valuable characteristics. As cobalt is a by-product of the Canadian silver mines, an abundant supply for this purpose is assured.

Our time does not permit us to dwell longer upon the wonderful achievements of research as applied to metallurgy in the field of these special alloy steels. It has been the special province of the writer to investigate that region of iron metallurgy which lies at the other extreme. Thus far we have been mainly discussing the influence upon iron of carbon alone or together with the rarer alloying metals. In the manufacture of ordinary steels, a certain group of elements is always present as impurities. Some of these impurities are desirable, while some are present only because it has until very recently been found practically impos-

FIG. 8.

Vanadium steel saw which was kept coiled for four years and when unstrapped came out almost straight.

sible to eliminate them on the large scale of operation made necessary by modern economic conditions. During the period of metallurgy which is comprised within the last century, men have been alive to the effects produced in iron and steel by the following elements which have often been referred to as the "big five." These are carbon, manganese, sulphur, phosphorus, and silicon. Owing to a peculiar condition of affairs that has arisen in the iron industry in America, we have now to add another common

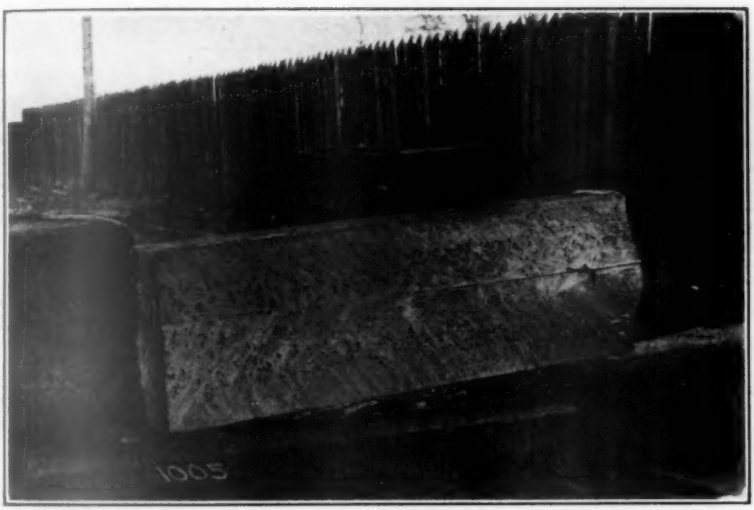
element of impurity, namely copper, which changes the "big five" which the ordinary iron analyst is called upon to determine to the "big six."

In 1905 the writer, who was then engaged in the conduct of certain research work in the United States Department of Agriculture, was called upon to make an investigation of the alleged extremely rapid corrosion of steel fence wire and other forms of steel used in agriculture. After a careful study of all the available sources of information, and an extended research inquiry in the laboratory, evidence seemed to be pointing strongly in the direction that a great improvement in many forms of steel would be produced if the five ordinary impurities then considered could be reduced or possibly completely eliminated. As the result of the publication of these researches and those of other workers in the same field, the electrolytic theory of corrosion was developed and is now commonly accepted as the explanation of the underlying governing principles upon which the rusting of iron and steel depends. In spite of its wonderful and useful qualities, ordinary impure iron and its derivative steel have the weakness of being easily attacked, not only by the moisture and oxygen of the air, but by all forms of acid action. The sources and ores of iron are all found in the highly oxidized condition, and iron is only won from this combination by the expenditure of enormous quantities of energy. Once divorced from its combination with oxygen, it shows a tendency to again unite with this element and thus return to its stable condition. One of the interesting and important fields for research, therefore, has been the study of this tendency toward oxidation and to devise ways and means of overcoming and, to as great an extent as possible, circumventing it. The electrolytic explanation of corrosion teaches us that the presence of the ordinary impurities in iron tends to stimulate the action and to throw the corrosive attack particularly upon certain points or nodes of an exposed surface, thereby producing that most dangerous form of corrosion, which is known as pitting or tuberculation.

It has already been shown that when a solution of salt in water is cooled toward the freezing point, it does not congeal into a homogeneous mass of salty ice, but a certain selective action takes place, resulting in a separation of the resulting crystals, ice and salt. The same tendency exists when impure masses of

mother metal cool down to the solidifying point. Some constituents crystallize out before others and become segregated. Segregation is one of the important problems that the modern research metallurgist is called upon to study, for it presents dangers from many different points of view if it is allowed to take place in an uncontrolled manner. If an ingot is segregated, the finished product of the ingot will be segregated and is liable to breakage or to corrosion damage, according to the nature of the product or the kind of service it is designed to endure.

FIG. 9.



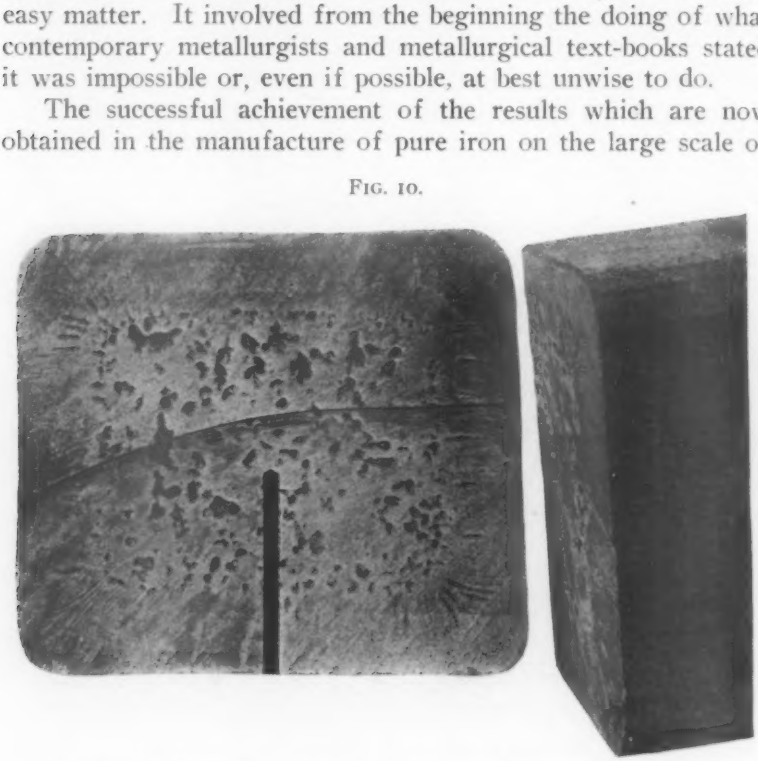
Longitudinal section, showing an open or spongy condition of a commercial steel ingot.

If segregation takes place as the metal cools and solidifies, the gases which are entrained or dissolved in the liquid bath cannot escape freely and therefore become entrained, producing an open or spongy ingot. Spongy ingots may be easier and less costly to bloom down than those which are solid and homogeneous, but there are, as the writer can testify, a number of honest and progressive manufacturers who are working to improve their ingots at the expense of very high cost in the maintenance of efficiently equipped research departments. It stands to reason that one way of overcoming segregation is to eliminate all alloying impurities, thus producing a pure

iron in which there is nothing dissolved which can possibly segregate. The solution of the problem of producing such a pure iron on the large scale of operation demanded under the conditions of modern social economics and modern industry has been no easy matter. It involved from the beginning the doing of what contemporary metallurgists and metallurgical text-books stated it was impossible or, even if possible, at best unwise to do.

The successful achievement of the results which are now obtained in the manufacture of pure iron on the large scale of

FIG. 10.



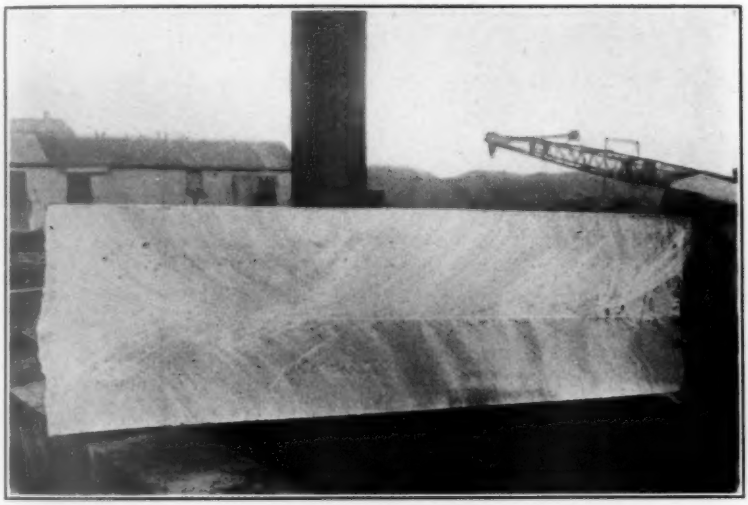
Cross section, showing an open or spongy condition of a commercial steel ingot.

open-hearth operation was not accomplished except as the result of very costly and strenuous research work in which determined men in the office, the mill and the research laboratory joined forces with a common purpose and with loyal energy. The writer is proud of the share he has had in this work and of the associations he has enjoyed with the group of men who have made it possible.

Where great strength is demanded, of course, pure iron is not suitable, but it has many interesting properties which differentiate it from ordinary steels or alloy steels. Pure iron is very soft

and malleable, and is capable of being most easily welded with the oxy-acetylene or oxy-hydrogen flame. A strip of this pure iron can be used as solder to join two ends or laps of the same material. It can easily be drawn into wire. Its electrical conductivity is 60 per cent. better than ordinary soft or mild steel. The comparative resistance of copper being taken as one, that of commercially pure, so-called ingot iron is 5.3, of charcoal iron 5.4, of Norway iron 5.8, of soft steel 8. For this reason, this pure iron can be and should be substituted for steel in the manufacture of third rails in the electrification of railways. Every saving in

FIG. 11.



Longitudinal section of an ingot, showing improvement brought about as the result of careful research work.

the electrical resistance of the conductor is figurable into coal at the boiler end of the system.

In fact, this pure iron finds many interesting new fields of application, but its principal value so far has been due to its well known and well proven slow and even rusting quality. The writer has had comparative large scale exposure tests of various sorts and kinds under his observation for a number of years, and the pure iron seldom fails to give a good account of itself.

It has recently been claimed that ordinary steel alloyed with a little copper, say about .20 per cent., yields a metal of superior

rust-resistant properties, and is therefore as good if not better than the purest iron. D. A. Lyon, speaking recently before this Institute,[6] voices this opinion in the following words:

" . . . the writer believes that there is more evidence to warrant the belief that the presence of copper in proper amounts in steel does prevent corrosion, rather than that it does not, or, as some claim, by reason of its being an impurity, promotes it."

I am one of those who do not agree with this opinion. It must be plain to every one that even if in some respects, notably in conferring an added resistance to an acid test,

FIG. 12.

A longitudinal section of a piped ingot, showing great density and freedom from blowholes in the body of the metal.

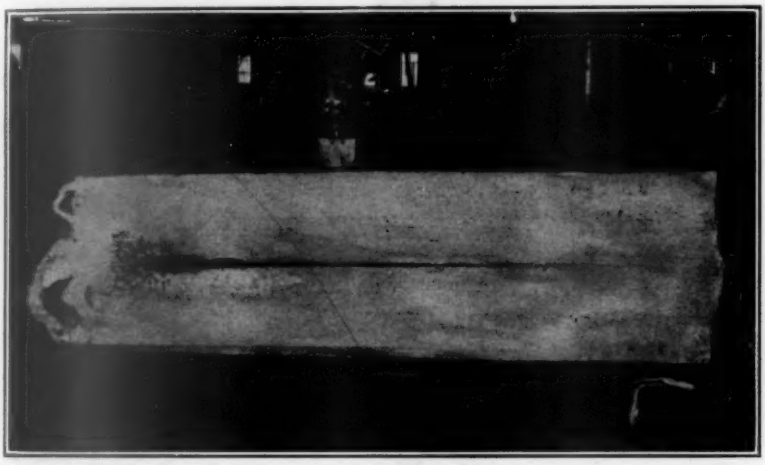
the presence of a small quantity of copper is held to improve the steel, its admission as a basis of specification introduces a grave danger. Copper need not be and generally is not purchased by the manufacturer for introduction into steel, as it is much simpler to employ a cheaper grade of scrap as a material of manufacture, which contains the copper in the form of machine wastes. It seems inevitable that behind the screen of coppered steel specification will lurk the cheap segregated metals that modern

[6] JOURN. OF THE FRANKLIN INSTITUTE, Vol. CLXXVII, No. 2, 192.

research is trying so hard to work away from. Homogeneity and lack of segregation are the goal on which every progressive metallurgist has his eyes fixed, whether his special product is iron or steel.

Several recent lecturers before this Institute have discussed the bearing and importance of the production of sound ingots on the iron and steel problems of the day. You have heard of piped ingots on the one hand and of spongy, blow-holed ingots on the other. Between these two awkward extremes the con-

FIG. 13.

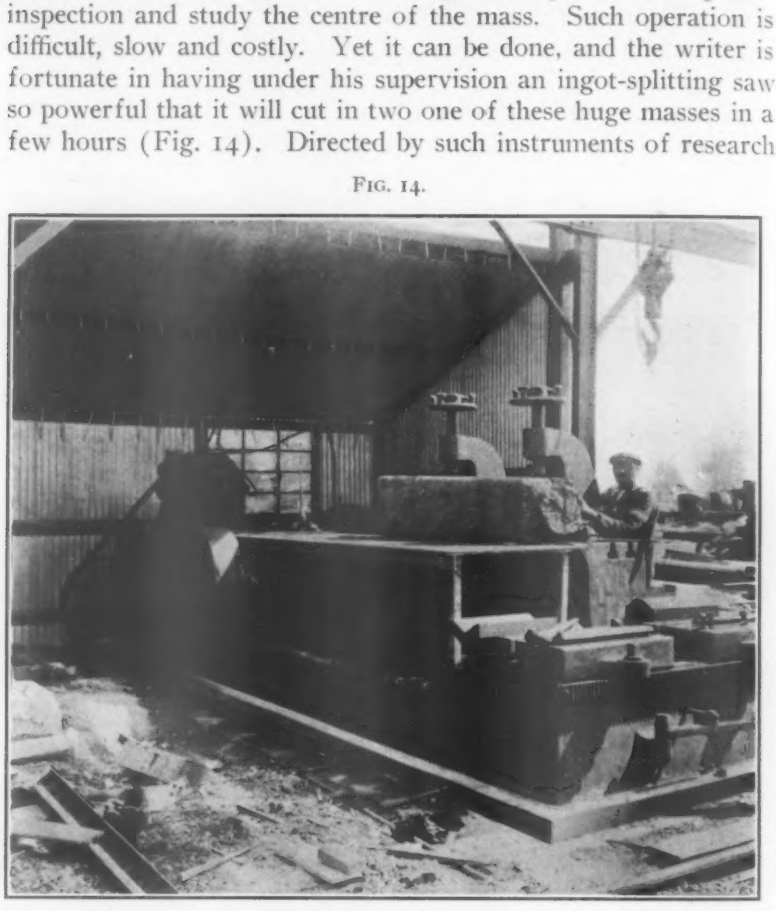


A longitudinal section of an experimental ingot, showing an extreme and dangerous form of piping.

scientious steel-maker is struggling as between Scylla and Charybdis. To a limited extent, the metallurgist has the making of sound ingots under control, but much remains yet to be learned in this respect. Five or six different methods or expedients for meeting this difficulty have recently been brought forward, but there is no record that any one of them has as yet proved its universal applicability. The difficulties attending this line of research are very great, as may readily be recognized. Modern ingots in big practice usually weigh at least 5000 lbs. and are 18″ x 20″ or more in cross-section and 5 or 6 feet long. If we vary our metallurgical practice, how are we to tell whether we have made any improvement? The only sure way is to saw a

number of selected ingots in two longitudinally, and thus open to inspection and study the centre of the mass. Such operation is difficult, slow and costly. Yet it can be done, and the writer is fortunate in having under his supervision an ingot-splitting saw so powerful that it will cut in two one of these huge masses in a few hours (Fig. 14). Directed by such instruments of research

FIG. 14.



An ingot-splitting saw at work. As the ingots measure 18" x 20" or more in cross section, this machine is very large and powerful.

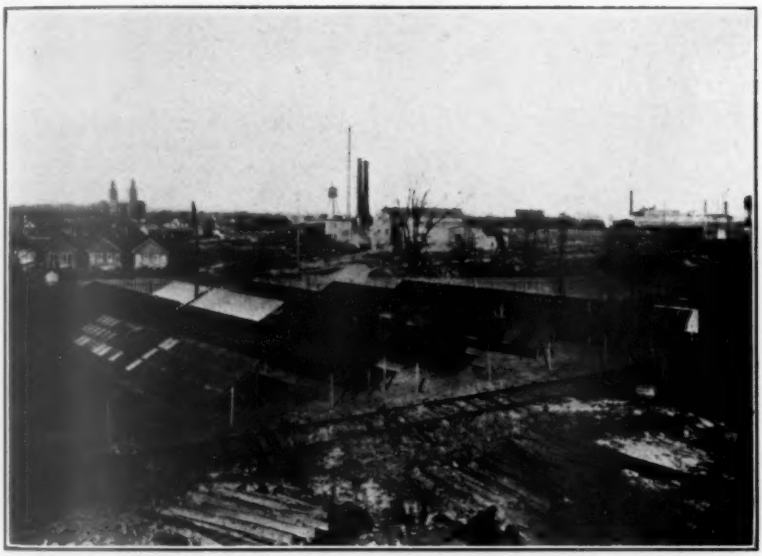
as this, progress is rapid and great improvement in quality both as to strength and rust resistance of product is constantly being made.

The possession of this ingot-splitting saw has made it possible to study corrosion problems with special reference to the interior condition of the original ingot. After an ingot is split and has been studied, it is possible to roll down sheet metal into the full commercial sizes from the ingot and then put the sheets

out under atmospheric and certain accelerated tests. By this means it is possible to follow up the problem in a more intelligent manner than probably has ever been done before. In the illustration in Fig. 15 a general view of the atmospheric corrosion proving grounds under the supervision of the author is shown, and it includes many hundreds of full-size sheets of many types, manufactured from iron and steel ingots.

An interesting test which has been devised, which although

FIG. 15.



A view of the proving ground where full-sized commercial steel and iron sheets are tested by the author for corrosion resistance properties.

an accelerated test shows some very extraordinary results, is illustrated in Figs. 16 and 17. Large hollow-walled boxes are made of corrugated test sheets nailed side by side as panels, and the hollow walls are then filled with either cinders or manure. By this means it is possible to get results on resistance to corrosion, of experimental materials, in from six weeks to six months, whereas in ordinary atmospheric tests generally several years are necessary before decisive results can be obtained, upon which any definite conclusions can be built.

In spite of the extraordinary vigorous competition and differ-

ence of opinion in respect to the manufacture of corrosion resistant sheet metal, it is the desire of the writer to come at the truth of the matter through the methods of scientific research. A few years more of this sort of investigation work should furnish dependable data upon which to base conclusions. In the meantime, the various announcements made by special interests, in

FIG. 16.

A new form of corrosion test. Hollow wall boxes built up out of test sheets and then filled with cinders or manure to accelerate corrosion.

regard to corrosion resistance problems, should be accepted only in the spirit in which they are made—that of a desire to obtain the largest possible market for their own particular type of product.

Probably no field of metallurgical research is more interesting or more important than the development of special steels for use in the manufacture of high-power electrical machinery. We are facing, if we have not entered, the age in which electricity will be the great universal servant of man's evolution. The research metallurgist has been quick to respond to the call of the electrical engineer and designer for special types of iron and

steel to increase the efficiency and lower the costs of dynamos and transformers. Time will not permit me on this occasion to discuss the contribution of metallurgy to this most important line

FIG. 17.

Illustration taken after 11 months' exposure in the box test, showing the failure of one type of sheet metal in competition with others. The gauge or thickness of the different panels is the same in each case.

of progress. There is material enough connected with the subject to call for a separate and special paper. It is interesting to note in passing, however, that it has been estimated, by a well-known electrical research engineer, that the metallurgical improvements

in transformer steels, brought about within the last few years by modern metallurgical research, represent a saving in money which would amount, if capitalized at 6 per cent., to approximately $15,000,000 in the experience of one great manufacturing company alone. The writer knows that this claim is not exaggerated, and such statements stand for themselves when they are vouched for by those who are familiar with the data involved in making such calculations. No better argument than this could be advanced to justify the claim that modern scientific investigators are continually making, namely, that properly guided research work pays; that it is not a mere refinement or trimming on the edge of industry but, on the contrary, is a business asset which should be set down at or near the top of the column when the cost of high grade production is being computed.

One more thought and I am done. Research work is not alone the servant of the producer. Its results ramify in every direction. It does not seek to cheapen the materials with which the human race is carving its destiny, by degrading them in quality, but it does cheapen them by seeking to improve the methods of their production with due regard to the end and object they are designed to serve. Scientific research work in a nation, as Germany has demonstrated to the world, is a national asset which should be understood and encouraged by all the people. In this country we are only just beginning to realize the importance of development along this line. Something has been accomplished, but, in closing this paper, the deathbed words of a great man recur to my memory: "So little done! So much to do!"

Instrument for Solving Spherical Triangles. ANON. (*Eng. News*, lxxi, 180.)—Describes, with photographs, an instrument called the "mechanical navigator," which solves mechanically, by the setting-off of angles on rotating arcs, all the problems in spherical trigonometry which arise in navigation. By manipulating the instrument a navigator may find in one operation a ship's position at sea from two sights, making allowance for the ship's run. This is equivalent to solving three spherical triangles simultaneously, thus avoiding the use of the method of the Sumner lines, or their treatment by the method of Saint-Hilaire. The result thus found mechanically is claimed to be within 2′ of arc, or less than the theoretical errors of the above methods. A detailed description is given of the method of use in certain cases.

PRODUCER GAS FROM LOW-GRADE FUELS.*

BY

R. H. FERNALD, M.E., Ph.D.,

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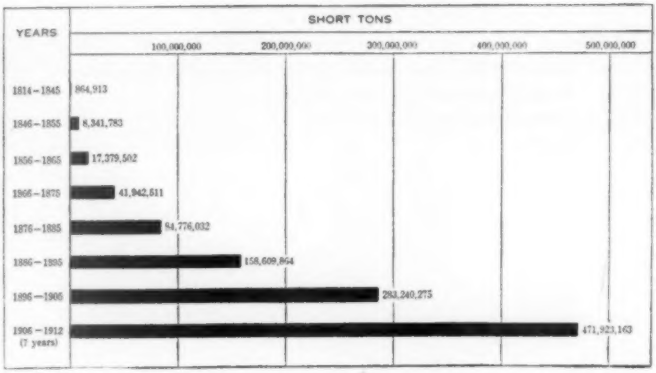
Member of the Institute.

THE Reports of the U. S. Geological Survey show that, if the rate of increase of fuel consumption in this country that has held for the past fifty years is maintained, the supply of easily available coal will be exhausted before the middle of the next

FIG. 1.



century. As is shown in Fig. 1, the production of coal in the United States increased from less than twenty million tons fifty years ago to nearly five hundred million tons in 1912; if the industries of the country continue to develop at a sufficient pace to maintain this rate of increase, then the limit of our coal supply will be reached in about 200 years. As a matter of fact, the fuel consumption per capita is actually increasing much faster than the population, so that the question of the continuation of this rate of increase is one of considerable importance.

It is interesting to note that the production of coal in the United States has been for some years greater than that in any

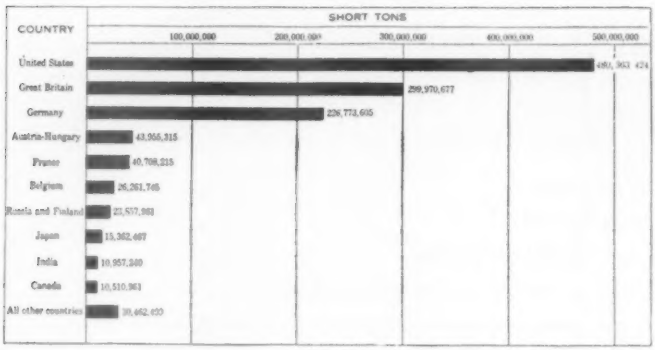
* Abstract of lecture delivered at the stated meeting of the Institute, November 19, 1913.

other country. The world's production of coal by countries for 1907—the last year for which figures are available to the writer—is given in Fig. 2.

The disposition of the coal fields in this country, as well as the relative areas of the different grades of coal, is indicated in Fig. 3. The limited supply of good coal makes it necessary to mine large quantities of sub-bituminous coal and lignite to meet future conditions. It will be noted that there is very little overlapping of the bituminous and lignite areas.

Most of the United States lignites do not weather well, but break down and crumble into fine dust when exposed to the atmosphere for any length of time. There are, however, extensive areas

FIG. 2.



of lignites in Alaska which stand up very well under weather conditions.

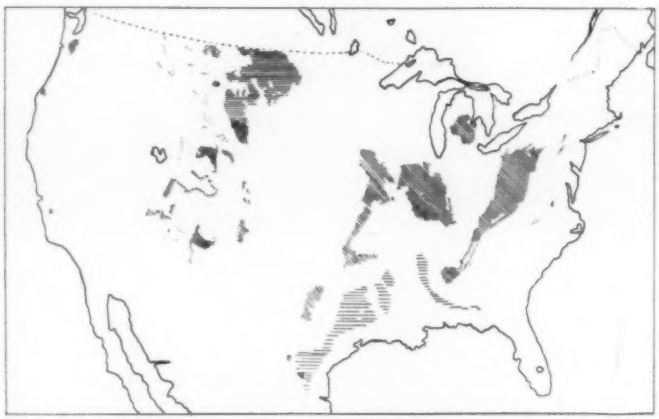
A great many low-grade bituminous coals and lignites may be utilized for power purposes by briquetting, and the use of this process industrially is gradually increasing. Briquetting, however, raises the price of the fuel by a considerable amount. It costs 90 cents to $1 per ton to briquette coal, and this large expense is practically prohibitive in competition with cheap fuel. On account of the expense, it appears that briquetted coal will hardly become adopted for large plant work, though this form of fuel undoubtedly serves well under certain conditions for domestic purposes.

Another low-grade fuel is peat. There are large deposits of peat in this country, and in Canada there are some 37,000 square

miles of peat area from six to ten feet in thickness. Peat is prepared in Sweden, Denmark, Germany and Russia, and is also secured extensively in Ireland and some parts of Holland. The distribution of peat in the United States is shown in the map, Fig. 4.

When it comes from the bog, peat contains about 85 per cent. water, but when "commercially dried" by exposing it to the sun, it contains from 25 to 30 per cent. moisture. Commercially dry peat has a heat value of about 8000 B. T. U. per pound, and

FIG. 3.



is very suitable for use in gas producers, as very little or no steam need be introduced with it.

In view of the necessity of utilizing, for the production of power, grades and varieties of fuels which have not until recently been considered economical, the U. S. Bureau of Mines has conducted a number of investigations on the making of producer gas from such fuels.

The introduction of the gas producer into this country for power plant work was made about the year 1900. In that year the number of installations was very few—perhaps two or three plants—but since then it has steadily increased. The total number of plants in 1911, of which the writer has record, was 660, and of these a large proportion were double installations, which were

not counted separately. The number of gas producer power plants in the United States at the present time is probably in the neighborhood of 1000. The total horsepower of such plants in the United States in 1900 was 2000; this has increased year by year until in 1911 it was between 160,000 and 170,000, some 80,000 of which was obtained from bituminous coal, some 70,000 from anthracite fuel, and about 10,000 from lignite.

Of the total number of plants operating in 1912, 84.5 per cent. used anthracite coal and 10.7 per cent. bituminous coal, while lignite was used in 4.4 per cent. of the installations. The anthracite plants, however, represented only 47.8 per cent. of the

FIG. 4.

total horsepower developed, the bituminous plants 46.3 per cent., and the lignite plants 5.4 per cent., while wood and oil developed the remaining small percentage.

Summarized data relative to producer gas plants in the United States, March, 1912, are given in Fig. 5.

The anthracite plants are scattered all over the country, though several are congregated around New York and Philadelphia. The lignite plants are chiefly in Texas and Washington; there was a marked increase in 1912 in lignite plants in the former of these States. The largest total horsepower is produced in New York, and the next in Missouri.

FIG. 5.

Summarized Data Relative to Producer-Gas Power Plants in the United States, March 1912.

FIG. 5.

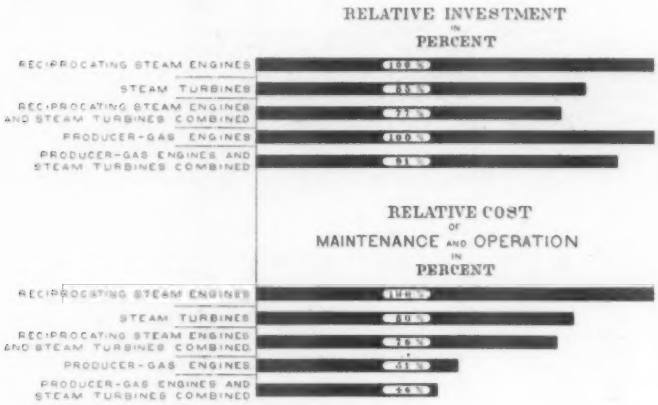
Summarized Data Relative to Producer-Gas Power Plants in the United States, March 1912.

	Horsepower												Percentage of total number		Percentage of total horsepower	
	Number of Plants			Total			Average		Minimum		Maximum					
	1909	1912	Percentage Increase	1909	1912	Percentage Increase	1909	1912	1909	1912	1909	1912	1909	1912	1909	1912
Anthracite coal:																
Over 500 H. P..	8	29	263	7,550	25,825	242	950	890	600	520	1,500	1,800	...	....	...	...
500 H. P. or less	407	581	43	40,550	63,645	57	100	110	15	15	500	500	...	....	...	...
	415	610	47	48,100	89,470	86	116	146	15	15	1,500	1,800	88	84.5	43	47.8
Bituminous coal:																
Over 500 H. P..	20	40	100	49,000	76,890	57	2,450	1,920	750	600	6,000	9,000	...	....	...	...
500 H. P. or less	17	37	118	5,150	9,725	89	300	262	35	25	500	500	...	....	...	...
	37	77	108	54,150	86,615	60	1,460	1,120	35	25	6,000	9,000	8	10.7	49	46.3
Lignite:																
Over 500 H. P..	3	3	0	7,275	7,275	0	2,430	2,430	525	525	3,750	3,750	...	....	...	...
500 H. P. or less	19	29	53	1,725	2,955	71	90	102	25	25	250	350	...	....	...	...
	22	32	45	9,000	10,230	14	410	320	25	25	3,750	3,750	4	4.4	8	5.4
Wood:																
Over 500 H. P..	0	0	...	0	0	...	....	....	...	...	....	....	...	....	...	...
500 H. P. or less	...	1	...	.....	500	...	....	500	...	500	....	500	...	0.1	...	0.3
Oil:																
Over 500 H. P..	0	0	...	0	0	...	....	....	...	...	....	....	...	....	...	...
500 H. P. or less	...	2	...	.....	325	...	....	163	...	100	....	225	...	0.3	...	0.2
Total.....	474	722	52	111,250	187,140	68	235	260	15	15	6,000	9,000	100	100	100	100

Factors which influence the installation of any particular type of plant are cost of installation and of maintenance, and economy. The average cost of producer gas installations is about equal to that of reciprocating steam engines; the cost of maintenance is, however, only about one-half, while the economy has been shown in several cases to be from two to three times as great. These statements are illustrated in Fig. 6.

At the Interboro Rapid Transit Company's Fifty-ninth Street Station, New York City, is one of the most efficient steam plants of which the writer has knowledge. At this plant 970 B. T. U. have to be put into the furnace to realize 100 B. T. U. at the

FIG. 6.


RELATIVE INVESTMENT IN PERCENT
RECIPROCATING STEAM ENGINES
STEAM TURBINES
RECIPROCATING STEAM ENGINES AND STEAM TURBINES COMBINED
PRODUCER-GAS ENGINES
PRODUCER-GAS ENGINES AND STEAM TURBINES COMBINED
RELATIVE COST OF MAINTENANCE AND OPERATION IN PERCENT
RECIPROCATING STEAM ENGINES
STEAM TURBINES
RECIPROCATING STEAM ENGINES AND STEAM TURBINES COMBINED
PRODUCER-GAS ENGINES
PRODUCER-GAS ENGINES AND STEAM TURBINES COMBINED

busbars. A theoretical gas plant devised on the same scale by Mr. Stott, Superintendent of Motive Power of the Interboro Rapid Transit Company, is shown in comparison in Fig. 7. In the gas plant 100 B. T. U. are obtained at the busbars when only 465 B. T. U. are charged into the producer.

Representing the figures in the above example in percentages, out of 100 per cent. of energy thrown into the furnace of the Interboro Rapid Transit Company's boilers, 10.3 per cent. is realized as useful work at the busbars. The theoretical gas plant assumed for comparison would deliver 21.5 per cent. to the busbars; this comparison is shown in Fig. 8.

At the Bureau of Mines Testing Station a 250 H. P. Corliss Engine, with 26.6 pounds water rate, with Heine Boilers, re-

quired 2060 B. T. U. charged into the furnace to secure 100 B. T. U. at the busbars, while a gas producer and gas engine, using the same fuel, required only 740 B. T. U. to deliver 100 B. T. U. at the busbars. In other words, 4.85 per cent. of the energy in the fuel charged into the furnace of the steam plant was delivered to the busbars, while 13.5 per cent. of that charged into the producer was delivered in the same way. These figures are shown graphically in Figs. 7 and 8 under " B. of M."

FIG. 7.

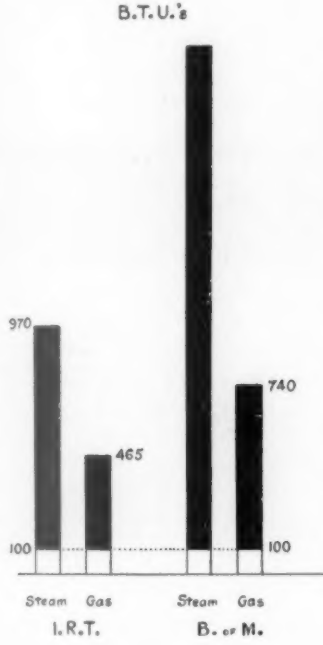
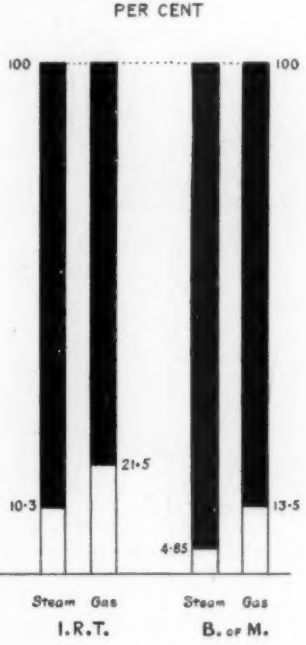


FIG. 8.

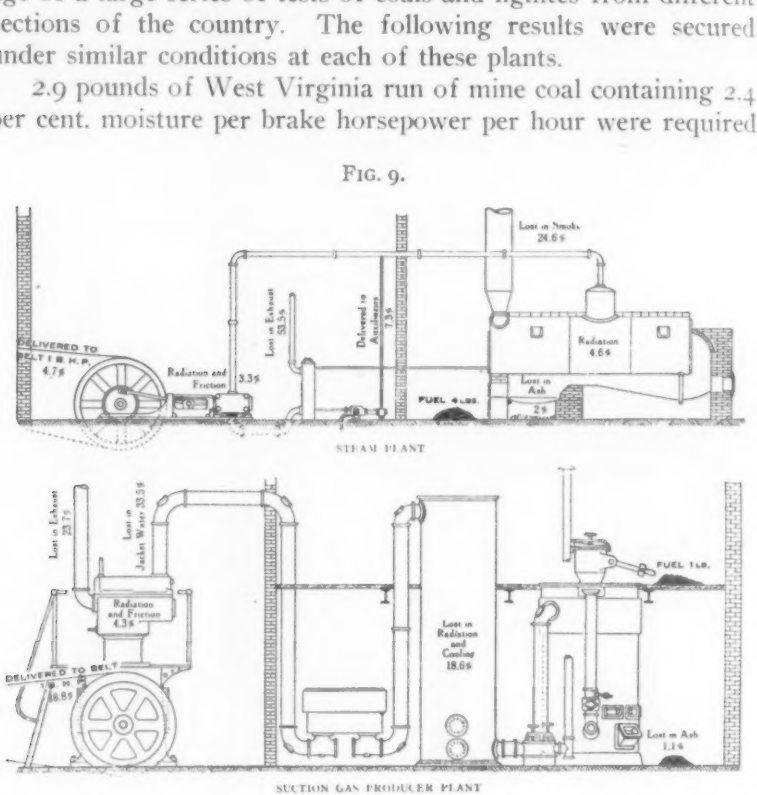


From a series of tests on a number of different Illinois coals, a comparison of the quantity of fuel per horsepower hour required in the steam plant and in the producer gas plant at the Bureau of Mines showed that, on the average, the former required 2.6 times as much as the latter. With fuel ranging in heat value from 14,000 to 15,000 B. T. U. per pound, the gas plant consumed approximately one pound, and the steam plant approximately three pounds per horsepower hour. Similarly, with fuels ranging between 7000 and 8000 B. T. U. per pound, the

gas plant consumed 2¾ pounds per horsepower hour while the steam plant required 7 pounds. These figures represent the average of a large series of tests of coals and lignites from different sections of the country. The following results were secured under similar conditions at each of these plants.

2.9 pounds of West Virginia run of mine coal containing 2.4 per cent. moisture per brake horsepower per hour were required

FIG. 9.



in the steam plant, while the gas plant required but 0.85 pound of the same coal.

With New Mexican run of mine coal, containing 19.6 per cent. ash, the gas plant required 1.1 pounds per brake horsepower hour, or just a little more than of the highest grade West Virginia coal, and very much less than the steam plant with West Virginia coal.

With West Virginia bone coal containing 44 per cent. ash which came in such form that a great deal of it resembled rock and, when struck with a hammer, threw out sparks, only 1.66 pounds per horsepower hour were required.

Many such fuels as the above can be utilized in producer gas plants, which require, as indicated, much less coal per horsepower hour than the corresponding steam plant.

Lignites usually run high in moisture, but make a gas of excellent quality. Less lignite was required per horsepower hour in the gas plant than of West Virginia coal in the steam plant.

Fig. 9 shows the distribution of heat in typical steam and gas plants. The heat losses in the two plants are as follows:

STEAM PLANT.

	Per cent.	
Heat lost in ashes	2.00	
Heat lost in radiation and cooling	4.60	
Heat lost in smoke	24.60	
Total losses in boiler	31.20	
Heat lost in radiation and friction	3.30	
Heat lost in exhaust	53.50	
Heat lost in jacket water		
Heat lost in auxiliaries	7.30	
Total heat losses in entire plant		95.30
Net efficiency of plant		4.70

GAS PLANT.

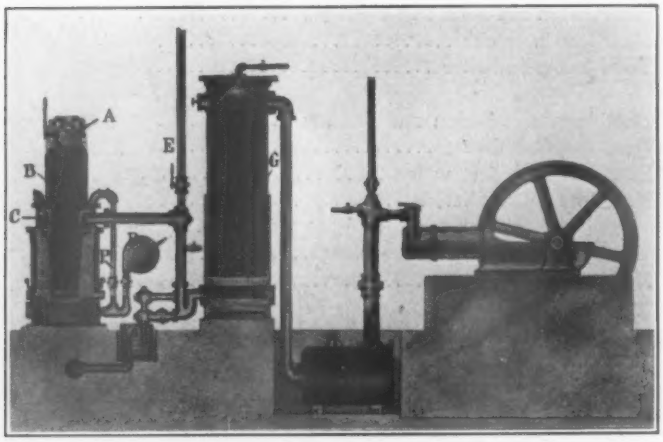
	Per cent.	
Heat lost in ashes	1.10	
Heat lost in radiation and cooling	18.60	
Heat lost in smoke		
Total losses in producer	19.70	
Heat lost in radiation and friction	4.30	
Heat lost in exhaust	23.70	
Heat lost in jacket water	33.50	
Heat lost in auxiliaries		
Total heat losses in entire plant		81.30
Net efficiency of plant		18.80

Original heat in the coal in both plants = 13,500 units per pound.

There are several types of gas producers now in use, among which are the suction type, the up-draft pressure type, the down-draft type and the double-zone type.

The suction producer is the simplest in form. A typical suction producer is shown in Fig. 10. The operation is as follows: The producer *B* is fed with fuel from the hopper *A*, which is provided with some feeding device so that the fuel may be dropped into the container below without admitting air. *C* is the vaporizer for vaporizing the water and mixing it with the air. The steam-saturated air passes down through the pipe *P* to the bottom of the producer. *D* is the starting fan. The hot gas leaving the producer enters a vertical pipe *E*, the upper part of which can be opened to the air to allow the poorer gas to escape when starting.

FIG. 10.



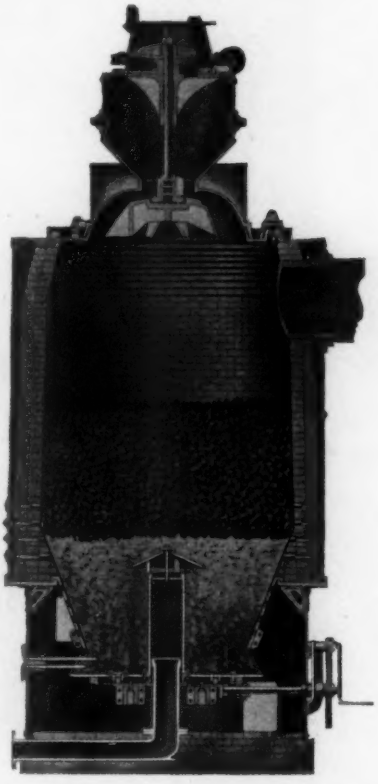
The gas passes down the vertical pipe through a water seal to the coke scrubber *G*. Tar collects at the bottom of *E* and runs into the tank shown. From the scrubber, the gas passes into the expansion box *H*, from which it is drawn by the piston of the engine into the cylinder.

The gas produced by the use of air and carbon only has certain excellent qualities for power purposes, but is rather low in heat value, and further than that, in making such gas there is a tendency for the temperature to rise to such a point that excessive clinkering is produced and fuel troubles are caused. The introduction of water or steam maintains the temperature at a sufficiently low point to prevent clinker formations.

When producer gas is made from coal, its constituents are carbon monoxide, a limited percentage of hydrogen and a small amount of marsh gas. Carbon monoxide is the main constituent.

Some gas producers embodying special features are shown in Figs. 11 and 12. The producer illustrated in Fig. 11 has a re-

FIG. 11.

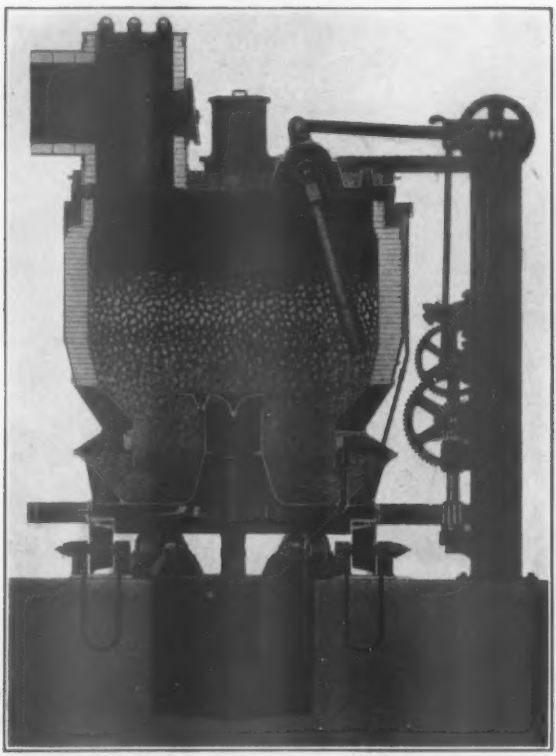


volving grate and an automatic feed. That shown in Fig. 12 is a mechanically-poked continuous gas producer.

A number of gas plants are provided with centrifugal tar extractors, for removing tar. Getting rid of this tar after it is removed is a very serious problem, and many attempts are being made to effect an increased utilization of this product commercially. Fig. 13 shows a system in which arrangement is made for converting the tar into gas available for use in the engine.

The method is to run two generators on a certain grade of fuel. The bed is a layer of coke; the fire is built on top of this and green coal is charged in over the fire. By this means an incandescent bed is formed. The draft produced by the exhauster draws the gas downward from the green coal through the incandescent bed, and the tarry compounds are supposedly converted

FIG. 12.



into gas. The products are then drawn through the wet and dry scrubbers to the holder. As shown in the figure, the exhauster is situated between the wet and dry scrubbers.

With the above system, after a certain period of operation, the tarry compounds, dust, soot, etc., tend to clog the fuel bed and the pull on the exhauster increases. Under normal conditions, the average pull is from 5 to 6 inches of water, increasing steadily.

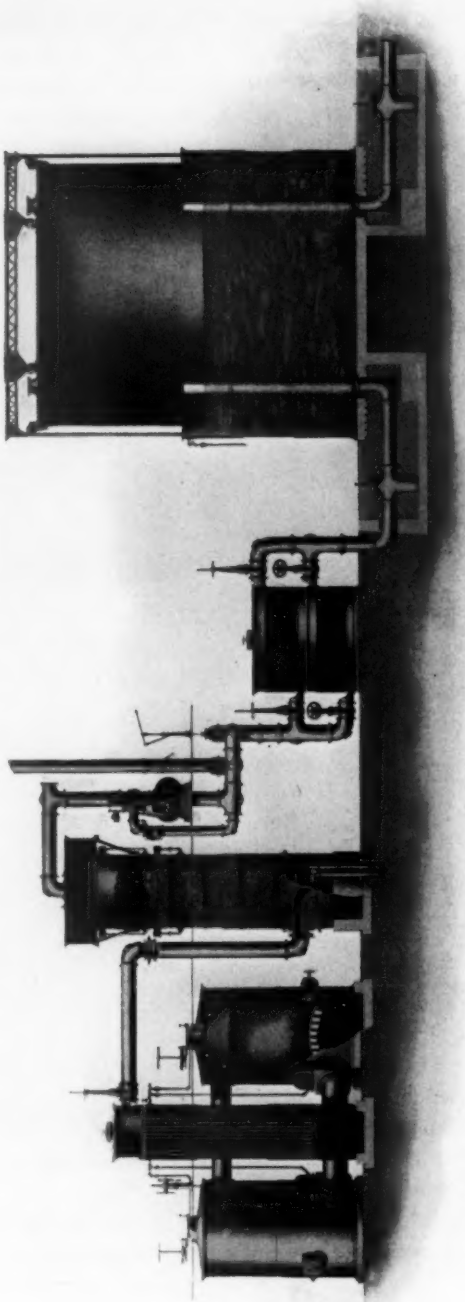
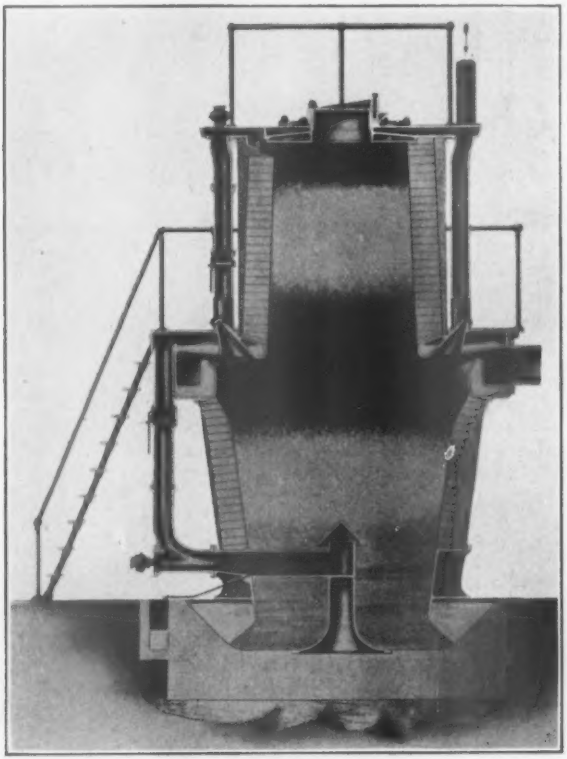


FIG. 13.

When the pull has risen to about 20 inches, the process of " shooting the bed " is gone through. The charging doors and the gas valve are closed, and steam under 60 to 80 pounds pressure is turned on under the grate. This jet of steam shakes up the whole fuel bed and sends the dirt, dust, soot, etc., through the by-pass into the other gas generator. After the process is completed the

FIG. 14.



gas has a heat value of about 200 B. T. U. instead of 105 B. T. U.

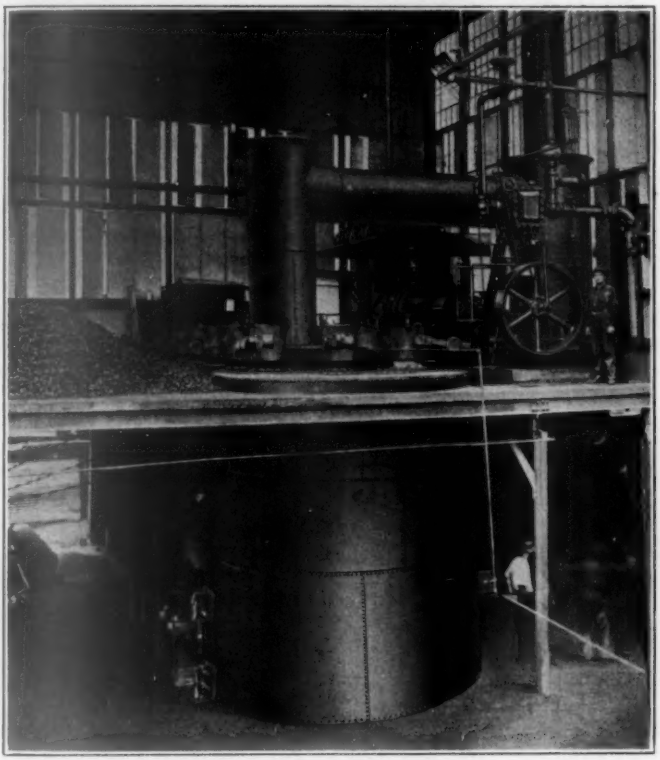
A double purpose is served with this type of plant, as two kinds of gas are produced—the first being commonly called air gas and the second water gas.

The system is used by a company in Boston which, however, requires no water gas, but simply gas for the engines. As a re-

sult, the bed is shot just as seldom as possible, sometimes not oftener than every six hours.

Another company uses a 4000-horsepower plant of this type. This company requires about 2000 horsepower for engine purposes, and the remainder of the gas for heating, tempering, an-

FIG. 15.



nealing, etc. In consquence, they shoot the bed just as often as possible, heating it up as rapidly as they can and then shooting it.

Tar can be satisfactorily converted into gas under the proper operating conditions. If, however, the temperature is not quite right, lamp black usually results.

In the type of plant described above, as the ash accumulates between the coke bed and the green fuel bed, the plant is intermittent and must be shut down in order to recharge. The charg-

FIG. 16.

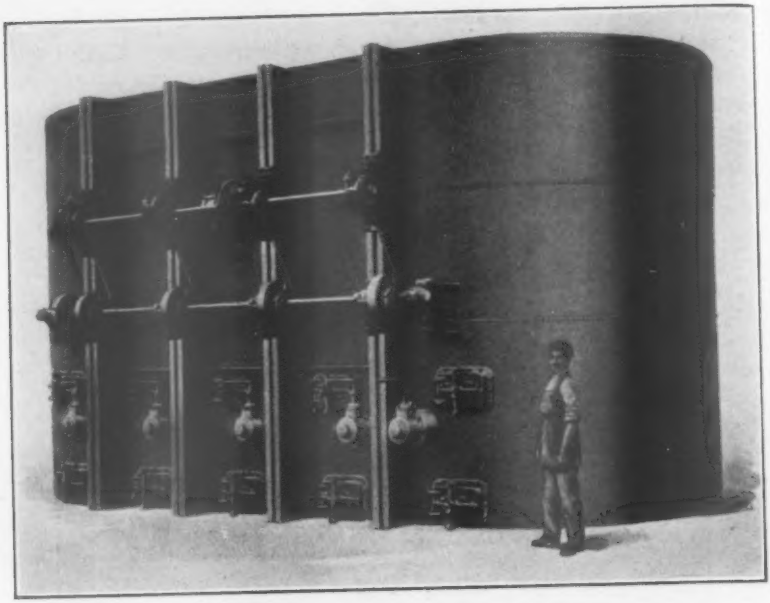


FIG. 17.

ing door may be opened and the coal charged directly into the producer, the whole operation being in full view of the operator.

Fig. 14 shows a type of producer with a double zone, in which are run two fuel beds, the object being to get rid of the tar. The coke which comes down through the upper zone becomes the main fuel for the lower zone.

A plant which was installed in the summer of 1913 and which illustrates the latest type of producer is shown in Fig. 15.

FIG. 18.

This producer is installed in Illinois, and is the largest single generator producer in the world. The producer proper is of simple construction and is made out of sheet steel and channels. It has semi-cylindrical ends and flat sides, as shown in Fig. 16. The capacity of the plant is forty tons of Illinois bituminous coal per twenty-four hours. The producer is equipped with what is known as the "Smith Type F Tar Extractor," having a capacity of 250,000 cubic feet per hour. This is not a centrifugal extractor, but consists of a double-tee arrangement; it has no moving parts and requires no water. The tar extractor in posi-

tion on the charging floor is shown in Fig. 17. In this figure may also be seen the gas exhauster. Fig. 18 is another view of the charging floor, showing the charging hoppers and the engine-driven gas pump.

FIG 19.

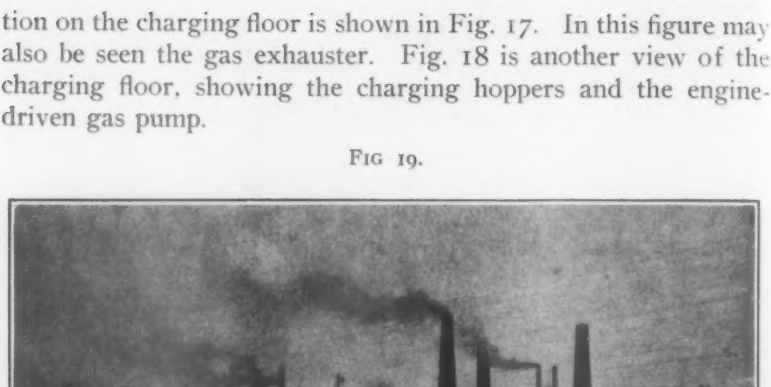


FIG. 20.

Centralization will undoubtedly become one of the essential factors in producer gas work, and even now railroads are considering the question of installing large central plants at the coal mines and utilizing the fuel there. Many important advantages are to be secured by the installation of such large plants, not the

least of which is the practical elimination of the smoke nuisance. A striking contrast between the old coal-burning methods and modern producer practice is illustrated in Figs. 19 and 20. Fig. 19 shows a typical view of coal plants in Staffordshire, England, and Fig. 20 shows a 16,000-horsepower producer gas station at Dudley Port, Staffordshire (recently enlarged to about 30,000 H. P.). This gas plant is one of the largest in the world. It is run as a by-product plant, and produces about 90 pounds of sulphate of ammonia per ton of coal. The gas is sold at a price which would correspond to 14 cents per 1000 cubic foot for city gas.

High-frequency Spectra of the Elements. H. G. J. MOSELY. (*Phil. Mag.*, xxvi, 1024.)—In the absence of any available method of spectrum analysis, the characteristic types of Röntgen radiation, which an atom emits when suitably excited, have hitherto been described in terms of their absorption in aluminum. This paper contains a description of a method of photographing the high-frequency spectra, which makes the analysis of the Röntgen rays as simple as any other branch of spectroscopy. It is intended first to make a general survey of the principal types of high-frequency radiation and then to examine the spectra of a few elements in greater detail and with great accuracy. The results already obtained show that such data have an important bearing on the question of the internal structure of the atom, and strongly support the views of Rutherford and of Bohr. Kaye has shown that an element excited by a stream of sufficiently rapid kathode rays emits its characteristic Röntgen reaction. He used as targets a number of substances mounted on a truck inside an exhausted tube, a magnetic device enabling each target to be brought in turn into the line of fire. This apparatus was modified to suit the present work. The kathode stream was concentrated on to a small area of the target, and a platinum plate with a fine vertical slit was placed immediately in front of the part bombarded. The tube was exhausted by a Gaede pump, charcoal in liquid air was also used sometimes to remove water vapor. The Röntgen rays after passing through the slit, emerged through an aluminum window 0.02 mm. thick. The rest of the radiation was shut off by a lead box which surrounded the tube. The rays fell on a cleavage face of a crystal of potassium ferrocyanide which was mounted on the prism table of a spectrometer. A photographic plate was mounted on the spectrometer arm, and both the plate and slit, S, were 17 cm. from the axis. If P is the part of the crystal where the radiation strikes the surface, and L the line on the photographic plate corresponding to radiation of definite frequency with glancing angle of incidence θ, then

$2\theta = 180° - SPL = 180° - SAL$, A being the position of the axis of the spectrometer table. A method is given of determining the angle SAL. Hence θ is known. The following elements were examined: Pt, Ta, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, and Zn. The photographs show that the spectrum of each element consists of two lines. The stronger of these is called α and the weaker β. The lines found on any of the plates besides α and β were most probably due to impurities. No other lines have been found; but a search over a wide range of wave-lengths has been made for only one or two elements and perhaps prolonged exposures, which have not yet been tried, will show more complex spectra. The prevalence of lines due to impurities suggests that this may prove a powerful method of chemical analysis. Its advantage over ordinary spectroscopic methods lies in the simplicity of the spectra and the impossibility of one substance masking the radiation from another. The similarity of the different spectra is shown by the fact that the two lines α and β remain approximately constant, not only in relative intensity, but also in relative wave-length. The frequency of β increases slightly faster than that of α. The same two lines, α strong and β weak, constitute the rhodium spectrum examined by Bragg, and they are obviously closely related in some way. One or two photographs taken with the radiation from platinum gave results in good agreement with those obtained by the electrical method, but no trace of the elaborate system of bands described by De Broglie was encountered. A discussion, based on Bohr's theory of atomic structure, is given of the meaning of the wave-lengths found for the principal spectrum line α.

Direct Recovery of Ammonia as Sulphate, without Distillation. W. STROMMENGER. (*Stahl und Eisen*, xli, 1694.)—For removing tar from hot gases previous to the direct recovery of ammonia as sulphate, the author describes a scrubber composed of two superposed chambers containing washing-tar up to the level of an overflow. The gases, brought to the desired temperature by means of a spray of ammonia liquor, are admitted to a number of inverted troughs immersed in the tar, and having serrated lower edges; two perforated plates are also immersed in the tar to insure intimate contact between the gases and the tar. The gases pass first through the lower and then through the upper chamber, and in the latter there is a filter above the tar level, to retain any tar spray. The washing tar is renewed by the tar separated from the gas, and the surplus runs continuously from the overflows. This apparatus has been in use for sometime in connection with 120 coke ovens at Ruhrort. No tar could be detected in the gases leaving the scrubber, and the quantity of ammonia in the gases leaving the saturator was only 0.75 gramme per 100 cubic metres. The ammonium sulphate was of a good, gray color, and contained 25 per cent. NH_3 on leaving the hydroextractor.

LOCOMOTIVE SUPERHEATERS AND THEIR PERFORMANCE.*

BY

C. D. YOUNG,

Engineer of Tests, The Pennsylvania Railroad Company, Altoona, Pa.,
Member of the Institute.

DISCUSSION.

MR. S. M. VAUCLAIN, Vice-president, The Baldwin Locomotive Works.—I have listened with a great deal of advantage to Mr. Young's discourse on superheaters. The indicator diagrams shown by Mr. Young in connection with high superheat and low superheat are very instructive, and if shown more frequently would revive the controversy which existed many years ago and which caused considerable discussion among the engineers of the United States Navy as to the relative value of low superheat compared with high superheat, resulting at that time, I believe, in a preference for low superheat. However, I believe it has been definitely proven that, for the high steam pressures which we are now using, high superheat is more advantageous, especially for locomotives, than low superheat. Of course, with low superheat, we do not have the same difficulties to encounter in the way of the deterioration of the metals employed in the superheater structure, and the deterioration of the low-pressure superheater is usually due more to the careless manner in which it is attended to than to its construction. The first low-pressure superheater which we (The Baldwin Locomotive Works) applied to a locomotive is still in use, and has required very little, if any, repair, whereas later superheaters which we have applied—several years later—have corroded and have been abandoned, and the locomotives have either been returned to ordinary single-expansion locomotives or high superheat has been substituted

On the Continent almost any locomotive of any importance is now fitted with the Schmidt type of superheater, which is a fire-tube superheater. More than one form of fire-tube superheater is used abroad, but in the main they are either a Schmidt superheater, an infringement of a Schmidt superheater, or a super-

* Continuation of article on page 83, vol. clxxviii, No. 1.

heater of a kind which may be considered an infringement of the Schmidt superheater. In this country many fire-tube superheaters have been devised, but they have all grown out of the idea advanced by Mr. Schmidt. In regard to the fire-tube superheaters, it is very pleasing to me to know that an inventor, even though he may be a foreigner, has been able to preserve and establish in general use an invention of so much value as we can attribute to the Schmidt superheater. I have, of course, opposed the Schmidt superheater at times in very many places—sometimes successfully and sometimes not successfully—but for commercial reasons only; and when those commercial reasons were removed I was very glad of the opportunity to admit that, for general use in locomotives, I considered the Schmidt superheater superior to our own type of low-pressure superheater or any other type of high superheater which we may have employed. Simplicity of construction and the general accessibility of the device also commend it, and in this particular device and in similar devices I feel that nothing has been left undone to make it not only accessible at all times, but easy of maintenance, and as a general thing it is never found fault with by the locomotive engineer who must use the locomotive, but is always spoken of very highly by him.

Now the advantage of using a superheater on a locomotive is, as Mr. Young states, to get more power out of the particular locomotive. That which gives a locomotive its power is its boiler, and any device which can be added to a locomotive to increase the effectiveness of its boiler increases beyond question the effectiveness of the locomotive. The original hauling power or starting power of a locomotive it is impossible to increase because that depends entirely upon the weight on drivers, but it is possible to increase the hauling power of the locomotive in tons and in speed of miles per hour—or, in other words, in horsepower. If you are developing your tractive power at forty miles, you can still increase the horsepower, for the horsepower depends upon the number of pounds of water you are able to evaporate in the boiler. If by a device such as the steam superheater you can get a certain horsepower with 20 per cent. less water or 30 per cent. less water, it is perfectly natural to suppose you can evaporate the same amount of water in this boiler and by the use of a superheater you can develop a speed of, say, 40 miles per hour and

haul 30 per cent. additional tons, and it is for this reason Mr. Young, I believe, makes the statement that the lighter-powered locomotives can have their hauling power increased by the addition of superheaters. But do not allow yourselves to be led astray by the fact that these locomotives can haul more tonnage because they can steam any more effectively, but they can haul more tonnage at the speed in miles per hour, and thus increase the earnings of the railroad company owning them accordingly and add to their own intrinsic value to that company. As locomotives have been increasing in size in the last few years, all of us have been struggling with the question of getting the greatest number of tons of freight over the road in a single unit, or at one train movement, and a train movement costs just the same whether it is large or small. The laws of the various States now prescribe the number of men that the railroad must carry to a train, and the principal number of these men are hauled in the caboose. The locomotive engineer really does the bulk of the work—when we dispose of the fireman—the conductor keeps tabs on his car numbers, and the remainder of the crew have a pleasant journey.

The advance in the weight of locomotives in this period has been phenomenal, and even though we thought that we had reached a fair size of locomotive—or a really large size—these locomotives do not prove quite so effective as their size should have made them. It was apparent to us that the reason for this is that we are not able to work the boilers at what they should do on account of the human equation—the human equation being the fireman. Therefore, the superheater man comes along, and applies superheaters to these particular locomotives, and we find we have a very much greater result in hauling trains at different speeds and in their general efficiency, although the demands of railroads for heavy cars and moving heavy tonnage have led us to go back and modify our compound system to include the superheater system, for the purpose of still further reducing the water rate per horsepower and adding to the hauling power of such a unit as can be conveniently employed. Such locomotives are constructed up to a tractive power capacity of about 100,000 pounds, and the limit is supposed to be reached, because even with automatic power we could not get the full capacity of a boiler; and, although it may not have been apparent to any of you here present that a Mallet locomotive, for size,

is a very much smaller type than any other locomotive in service, at the same speed at which these engines were operated and with the use of superheaters they seem to be a very desirable engine. Take the case of the automatic stoker; general opposition was made to the introduction of an automatic stoker, because it was said if a fireman was able to shovel the coal there was no necessity for applying automatic devices for this purpose. The result, however, of the experience with various automatic stokers has boiled the art down to probably one or two devices; one device especially is most effective, and, in my judgment, has solved the question of the compounding of locomotives. We have been able lately to construct, for one of the most progressive railroad presidents in the United States to-day, a locomotive of 160,000 pounds tractive force, and which, in our judgment, and from its ease of movement and its apparent life before any trial in service, is going to be a very successful unit of power. Now, such a locomotive has been arrived at by the careful and intelligent employment of the first principles of locomotive economy, the uniformity, similarity, and the continuity between the different sections. This locomotive is in three sections, with three pairs of cylinders, three sets of driving wheels, one tubular boiler, and an ordinary locomotive engineer and fireman. The compounding of the steam is in the ratio of two to one, which ratio is suitable for superheated steam. The superheater used is a Schmidt superheater similar to the one shown to you to-night by Mr. Young, and is capable of reducing the water rate from 24 pounds to 16 pounds under proper conditions. And, in addition to that, this locomotive has been equipped with a mechanical stoker for supplying coal to the fire and properly distributing it over the surface of the fire; it works admirably, and is successful in every way for firing this locomotive, which will require about 11,000 pounds of coal per hour. No effort whatever on the part of the fireman, with the exception of properly attending to the valves running the engine which drives the firing mechanism, is necessary.

Therefore, you see that, at the present time enjoying the advantages of these economical mechanical inventions of the past one hundred years, the future generation, commencing now in the year 1914, is going to really build large units of power for railroad transportation, and in a few years from now we will look back upon these insignificant pigmies with which we have

been transporting trains throughout this country and smile that we did not tumble to these various inventions many years ago.

MR. F. H. CLARK, General Superintendent of Motive Power, Baltimore & Ohio Railroad.—There is very little more that I can say that would be of interest to the members. Mr. Young's paper covers pretty well the theoretical side of the matter, and he explains very clearly some things that I haven't understood, or had understood imperfectly, perhaps, and, on the whole, I think it is the best superheater paper I have ever heard—and I have heard quite a number of them—because it is so up-to-date, and it gives a great deal of information derived in a very scientific and accurate way.

I do not think there are any comments on the paper that I care to make. I am here to-night more as a learner and listener than for any other purpose, and I am very glad, indeed, to be here.

MR. C. B. YOUNG, Chicago, Burlington & Quincy Railroad.—I think there is nothing that I can add to Mr. C. D. Young's paper on this subject.

His work on superheat has been far in excess of any work that I know of by any other individual. He has delivered a paper which I do not feel competent to discuss.

MR. GEORGE L. BOURNE, Vice-president, Locomotive Superheater Co.—I think, as Mr. Clark stated, Mr. Young has covered this subject so well that there is hardly any room for discussion. I very much appreciate the opportunity of being here and listening to the paper, and it is probable that very few appreciate the amount of research work and trouble that Mr. Young has undertaken in going so deeply into the prior art and history of locomotive superheaters.

In studying the early efforts in the prior art, additional light might be thrown upon the earlier designs of superheaters, particularly those which resemble the later types in use to-day. In studying the earlier designs, as Mr. Young has shown them, you cannot help being impressed with the fact that the investigators, while they were working along similar lines that we are following to-day, did not seem to be in full possession of just what was necessary for the practical operation and maintenance of a smoke-tube superheater. A close analysis of the de Montcheuil design discloses the fact that this inventor's only idea in adopting a bent

tube, either entering or coming from the smoke-flue, was simply that he had to get into a smoke-flue in order to do his superheating. He realized that, and he also realized that after he got in he had to get to the cylinder in some way. Other than that, I don't see that there can be any similarity between the de Montcheuil design and the modern smoke-tube superheaters. In accomplishing the above end of the interchangeability of the units was sacrificed, and the arrangement of the units in the boiler was so complicated that they could not be detached from the heater selectively, but had to be withdrawn in the respective reverse order from which they were applied. In other words, the last unit applied would have to be taken out first.

It is also somewhat interesting, by reference to Dr. Schmidt's design, to note that it has hardly been changed in any way not exactly as we use it in this country, but as it is used in Europe. The difference between European and American practice is in the matter of detail, and is accounted for by a difference in maintenance and operating conditions.

It might be of passing interest to know that the courts in Europe have also held that de Montcheuil in no way anticipated the fundamental idea of the single- or double-loop superheater, having its ends bent to the header and detachably fastened, as is the standard practice in this country. We know from a practical standpoint that in order for a superheater of this type, having units in the smoke-flues, to be not only satisfactory as a superheater, but practical in operation and maintenance, the units must be easily detached. Any of you who are familiar with the maintenance of a locomotive know that it needs attention at some times, and the facility with which this attention could be given, I believe, was one of the principal reasons for the success of what is known as the Schmidt design. Schmidt fortunately realized that it wasn't so much a question of engineering practice, but in the design he produced at that time, he was working to what he knew would be a permanent mechanical arrangement.

With reference to smoke-tube superheater designs where side heaters are employed, practical experience has disclosed the fact that disastrous wire-drawing may always be expected, and this is corroborated by the general application of cross-over pipes, where these designs are being used, in an endeavor to overcome the wire-drawing effect.

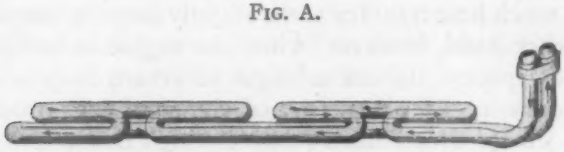
Mr. Young's investigation on the varying length of units is of much interest, and it is pleasing to know that the results obtained by him corroborate not only the engineering practice of to-day, but also the results of numerous European tests which were undertaken in past years by the European Schmidt Company.

As to the varying lengths of the return loop, it is very essential, in studying this question, that the complete range of the operation of the locomotive be considered. In other words, what might be an ideal length of return loop for an engine operating at 15 per cent. cut-off would not be so ideal a length for an engine at 50 per cent. cut-off; so that in designing a superheater for a locomotive, the superheater engineer or whoever is responsible for the design has to take into consideration the varying conditions under which the engine will be operated. Admitting, for the sake of argument, that at certain times the temperature of the steam in the return loop is slightly above that of the flue gases, the extremely low conductivity of superheated steam will not permit of much heat transfer at the slightly varying temperatures. On the other hand, however, when the engine is working to a reasonable capacity, the extra length of return loop is essential and necessary in order to permit of complete drying out of the saturated steam, which has a relatively high conductivity, or, in other words, to permit, preparatory to the superheating, or the conversion of the fluid into a perfect gas by the attainment of a high degree of temperature, the elimination of the wet-core, which has always bothered the superheating engineer.

Mr. Young spoke on the question of a higher degree of superheat. So far as the superheater company is concerned, that is just a question of when the American railroad mechanical man believes he has come to the point where he will have no difficulty in operating an engine with, say, 750° total temperature. Now, with regard to the varying types of units, if the attainment of a high degree of superheated steam efficiency were all that entered into the problem, the design of units looped as shown in Fig. A, would satisfactorily fill the requirement. In other words, that particular design of unit would permit of escaping from the saturated side of the header entering in the path of the gases and remaining there as long as possible, collecting such superheat from the lower temperatures at that end of the flue, passing through to higher temperatures, and in order that we might

retain the maximum temperature of the steam, we would deliver the steam from the path of the gases as quickly as we could. That would be as near an ideal unit as we believe could be secured in the smoke-tube superheater, but I wouldn't like to say what I think as to its practicability or as to its maintenance. And there is another point: The conditions are so variable in locomotive operation that it would be rather hazardous to base a design upon any particular steam consumption. It must be remembered that the superheater company has to take the locomotive boiler as it is, and do the best it can. We have restrictions, and about the best we can get out of the average boiler under the operating conditions we have to contend with in American practice, and all that we believe is desired under American operating conditions, is approximately 650°, an average of from 600° to 625°, except at long cut-off and fairly high piston speed, and we don't wish to go over 650. It might be of interest to know that in

FIG. A.



some of the European countries where they have been operating superheater engines for some eight to ten years they have arrived at the stage where they say, "We would like to have a little more superheat. Our coal costs a great deal of money, and if we can get a horsepower for 16 or 17 pounds of steam with 650°, why we would like to get it just a little lower." And there are quite a number of engines that are operating with total temperatures in the neighborhood of from about 725° to 740°. Thank you, gentlemen.

MR. GEO. M. BASFORD, American Locomotive Co.—I hardly feel competent to discuss this paper of Mr. Young's. I should like to say, however, a word in appreciation of the paper itself, and of the magnificent testing work which made possible the presentation of these data this evening. I should also like to say a word of appreciation of the Pennsylvania Railroad Company and its thoroughgoing methods which make these tests possible, and of the great generosity of that railroad company and its pro-

fessional spirit in bringing this information out so quickly and giving it so freely to the world.

I certainly appreciate being here to-night, as a privileged listener, and I am sorry that I cannot add anything to the material information on the subject.

MR. H. B. OATLEY, Locomotive Superheater Co.—I agree with all that the speakers have said as to the value of the paper Mr. Young has presented. There is no contribution to the literature of the locomotive—and the locomotive superheater in particular—that has added so much as this paper. The historical part of it is of especial value, and will become more so as time goes on. The data that have been brought out, as Mr. Basford has stated, from the Altoona testing plant, are recognized throughout the world. I recently came across some of the English engineering papers that referred to the tests, and the leading engineering association of Great Britain has recognized the value of these data for European roads. At the particular time the question came up, the topic of this evening was under discussion there, and it was regretted that they did not have in their own country data on superheaters such as have been presented from Altoona. They did not at that time have the particular series of tests that Mr. Young has given to-night.

The points that Mr. Bourne has brought out I think cover most everything that I could say.

The reference that was made in the paper to the possibility of an improvement, by some modification in the form of the units, bears with it, I think, a lot of uncertainties. It would demonstrate that a lot of changes could be made in the units that were going to decrease the efficiency of the superheater and of the boiler, and naturally of the locomotive as a whole. Whether there can be any improvements as mentioned in the statement Mr. Bourne has made seems open to discussion.

One point that occurs to me is in connection with the series of tests that were run on what, I think, might be termed the half and three-quarter returns. By shortening the return loop and moving the front return bend back into the flue a change in the area for the gases is brought about ahead of the maximum obstruction. In practice I believe that this wouldn't be as beneficial as it showed up on the testing plant, for the reason that flues would be more likely to clog up, which would decrease effi-

ciency. I understand that on each test they insured clean flues by having blown them out after a run of only an hour or an hour and a half. To me it would seem a decided disadvantage to shorten the unit in this manner.

I don't know as there are any other points that I could take up without consuming altogether too much time. I thank you for the privilege of speaking here this evening.

MR. OLIVER CROMWELL.—I think the profession will be very grateful to Mr. Young for this paper, and the pains he has taken.

There is one other side we might dwell on that probably would be of benefit to the railroads. A few years back it had become quite a serious question to employ labor for stoking the locomotives. I believe in the future this question is going to be very easily solved when they learn that there is no particular manual labor in connection with the firing of a locomotive. That is going to be a great help in solving this phase of transportation, and I believe the railroads and the locomotive manufacturers would do well to very thoroughly spread these views among the locomotive firemen of this country, and it will encourage a better class of young men to enter the service, with the net result of a decided improvement in the man who operates the machine.

MR. G. R. HENDERSON, Consulting Engineer, The Baldwin Locomotive Works.—There is one point that has not been brought out especially, and if we can get any information on it I think it would be very interesting, and that is: what relation does the velocity of the steam in the superheater pipes bear to the superheat? We are generally accustomed to thinking of material that it will get hotter the longer it is exposed to a heat, but there have been statements made at times that the superheat of the steam was really increased by causing it to flow through the pipes with a greater velocity.

Now it was shown on these slides to-night—some of these curves—that with the greater velocity of the steam when the boiler increases, for instance, from 25,000 to 55,000 pounds of water per hour, there was an increase in the superheat, but it must also be true—it was shown in the tables—that there was a very large increase of heat in the smoke-box, and also in the fire-box, and, of course, in the flues. Now a large part of that increased superheat was due to the increased temperature which these superheater flues had obtained. I do not know whether

any experiments have been made on this subject or not. If anyone here knows of them, I think it will be very interesting to have some testimony on them to-night.

MR. OATLEY.—It is very difficult to get any figures on that. I think probably Mr. Young will be able to answer that fully, or at least very much more fully than anyone else, because they must have made some analyses from the results they get at the testing plant.

A MEMBER.—I would like to ask how much superheat was induced at the time the exhaust valve was opened. I cannot see where there is any gain with the superheat going out of the exhaust valve.

MR YOUNG.—Mr. Henderson has raised a question as to the effect of velocity of flow upon the superheat. We have not done any direct work on the question, but we have information which indicates that unless a high velocity is provided in the transmission pipes for superheated steam there will be considerable loss; and if that is the case, it would seem as though the converse would be true, namely, that high velocity would be required in order to prevent loss of superheat. In other words, the maximum superheat would probably be obtained for a given heating surface in a given arrangement with the tube shown by Mr. Bourne; in this the direction of the steam is purposely reversed so as to get a high velocity as it returns, and break down what is known as the wet core of the superheated steam pipe due to the low conductivity of superheated steam. The steam must be broken up, and it was really with this thought in mind that the experiments with the spiral tubes were made. In the spiral tube, the thought was that it would break the wet core in the unit, and in that way influence the primary conductivity of the steam passing through; but as you saw from the experiments with that tube, this wouldn't apply in stationary practice. With a locomotive, there are no advantages to be gained by the slight increase that might be obtained in steaming action. It wasn't a desirable condition. In other words, we lost power, and anything that detracts from the power of a locomotive is detrimental to the purpose, for the locomotive is built for power and the power depends upon the boiler. It is unfortunate we haven't any information, but I believe this: that the more you reverse the steam without excessive

wire drawing, the better the superheat will be for a given superheating surface.

In stationary practice there is one form of superheater used very extensively abroad and in this country, in which the velocity is apparently made high by introducing a core in the unit so as to expose the steam to as thin a surface of metal as possible. In other words, the core in the unit breaks down the steam as it flows through.

A question is raised as to the temperature of superheat in the exhaust. We have made experiments at the testing plant in order to determine this question. To my knowledge, there is no device made that would record the temperature of the exhaust steam. The steam passes through a piston valve to the cylinders and thence through the valve again and out, but it is almost impossible to locate a thermometer except in the exhaust passage. Admission and exhaust are through a common passage, and therefore to get a true temperature of the steam at point of release is almost impossible unless you have a thermo-couple introduced and removed at each stroke. We have found, however, that we can obtain economy—and good economy—with fairly high superheat going out of the stack. Of course, that design which has produced the least waste would probably be the preferred design, but the load of a locomotive varies from practically nothing when drifting to its maximum at high speeds, or to a maximum at low speeds with very heavy load, and, therefore, the question of the amount of superheat is largely one of practice in maintaining the lubricant and the packing in the parts, rather than what superheat is discharged from the exhaust. In another bulletin, issued by the locomotive testing plant, we have shown the effect of high exhaust temperatures, and we find that with high superheat and short cut-off, even though we have considerable superheat in the exhaust the economies are considerable and the water rate is apparently little affected by the superheat which leaves at that point. Our readings show that the superheat in the exhaust will never be less than 15°, as measured, and will run as high as 70°, the temperature at admission being from 160° of superheat up to 300° of superheat. Of course, the longer the cut-off the greater the loss, both due to the lack of expansion in the cylinder and to

the fact that the shell has not the time to lose its temperature at the exhaust.

A MEMBER.—What kind of oil have you found best for use with the superheater, what kind in the piston, and what kind of packing?

MR YOUNG.—We use a petroleum oil compound having a flash point of about 575°, mixed with from 10 per cent. to 20 per cent. animal fat. The particular trouble is in maintaining the lubrication at the time the engine is running and when it is drifting. The main difficulty is that the heavy gases are frequently dragged into the cylinder, and they present a coat of carbon, so that the wear is very rapid. This practice seems to indicate that a close-grained cast iron, rather hard, will give the greatest service life. A casting should be just about as hard as can be machined to produce the proper surface. It is our practice to introduce oil with a hydrostatic lubricator, but we are experimenting with a mechanical lubricator which will introduce the oil regularly, and, so far as our experiments have gone it would appear that mechanical lubricators carefully handled will produce better results than hydrostatic lubricators.

We use for piston packing a soft metal. This gives considerable trouble when the engines are operated for a long time with long cut-off. We have no trouble in our valve steam packing, due to the fact that we use inside admission.

A MEMBER.—I have never thought of the possibility of using any animal fat in the oil, because we have such high temperatures. I use a mineral oil.

MR. YOUNG.—The reason we do that is frequently when engines are moved about we supply a small amount of animal fat, and under those conditions we will be sure after the engine gets on the road it will adhere, and the animal fat is used on superheated steam engines.

A MEMBER.—It might be a good idea when the engine is drifting to put your saturated steam in the cylinder. I have done that, and I don't think you would have any trouble.

MR. YOUNG.—I think that is a very good remedy for our troubles. I am sure there is no invention on the market that will do so.

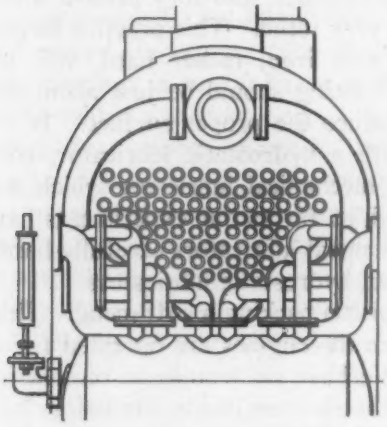
MR. HENDERSON.—This has been a very instructive presentation, and especially we appreciate the fact that Mr. Young has

given us this talk just as he is convalescing from a very severe sickness, and I should like, as a recognition of that, to take a rising vote of thanks to Mr. Young for his efforts in presenting to us to-night this very interesting paper.

CORRECTION.

Vol. 178, page 5, Fig. 3, substitute the following:

FIG. 3.



DE MONTCHEUIL'S SUPERHEATER, 1850.

Shrinkage of Alloys. ANON. (*Amer. Mach.*, xl, No. 22, 938.)—The excessive shrinkage of brass or bronze alloys necessitates a core which will be crushed readily by the molten metal. Large cores should be made with a soft interior, and this is generally accomplished by filling the interior of the core with cinders, powdered coke, or similar material. The core material must be fine, and this requires the use of finer sands for brass-foundry cores than those usually used in iron foundry work. When a brass casting has been poured and is shaken from the mold, care should be taken to keep the core sand from mixing with the molding sand. The cores for brass and bronze castings are sometimes blown out by shaking out the molds while the castings are still fairly hot, and then dipping the castings in water. The steam generated in the cores blows out the core sand, and gives the castings a better color. Iron castings would be broken by this treatment, but brass castings are rendered softer.

CELEBRATION OF THE THIRTIETH ANNIVERSARY OF THE INTERNATIONAL ELECTRICAL EXHIBITION, HELD IN PHILADELPHIA IN 1884, UNDER THE AUSPICES OF THE FRANKLIN INSTITUTE.

THE National Electric Light Association holding its thirty-seventh annual meeting in Philadelphia the week beginning June 1st, and this year being the thirtieth anniversary of the above Exhibition, the officers of the association felt that some part of their meeting should be devoted to the commemorative observance of the event; accordingly the evening of Wednesday, June 3rd, was set aside for this purpose, and the Institute invited to conduct the meeting. Invitations were extended to the members of the National Conference of Electricians of 1884, the Committee on Exhibitions, the Board of Examiners, the Guarantors and Exhibitors, and others taking a prominent part in this exhibition. Among those invited to speak were Messrs. Brush, Sprague and Rice. In introducing Mr. Rice, President Clark, of the Institute, who presided said:

"Gentlemen, and members of the National Electric Light Association, and ladies: This meeting is in commemoration of the International Electrical Exhibition, held in Philadelphia thirty years ago, under the auspices of The Franklin Institute for the Promotion of the Mechanic Arts.

"The fortuitous circumstance of my present occupancy of the office of president of the Institute is solely responsible for my presence in the company of the distinguished scientists now before you, and for my having the honor of presiding over this notable gathering. But however accidental may be my presence at a gathering of the notables of the electrical industry, the presence of The Franklin Institute is appropriate and logical, and this not alone because of its controlling influence in the great Exhibition of 1884. When and wherever the devotees of your wonderful and wonder-working art are gathered, there, if the galaxy be complete, will be found the spirit of the great Franklin and the bodily presence of the venerable Institute that bears his

name. Not one of you—in whatever of the many branches of the electric science you labor—can trace the progress of your art back to its origin and not come in contact with this old electric generator [here points to the Franklin electrical machine on exhibition], designed, built, and used by Benjamin Franklin; and few of you upon such a quest can escape passing through the classic building on Seventh Street which is the home of the Institute.

"For two generations before the beginning of what may be called the electric age—the age that knew Edison and Bell and Weston and Brush and these other gentlemen in their early youth; for more than a generation before the Atlantic cable was laid; for a period beginning while the immortal Morse was still making indifferent marble statues, and the dream of a girdle about the earth had not come to him—for all that time, and ever since, The Franklin Institute has been promoting the science of electricity. Recording, disseminating, illustrating, encouraging, and rewarding, it has rendered continuing service to four generations. The science and art of electric generation, distribution, and utilization, no more than any other of the mechanic arts or sciences, can write its own comprehensive history and escape acknowledgment of obligation to the Institute and to the great man whose name it bears.

"The greatest individual service rendered to the electric art and science by The Franklin Institute was the International Electrical Exhibition that we are commemorating to-night.

"In the presence of the many gentlemen wise in the science and skilled in the art of electrical generation and utilization, who helped to make the Exhibition a success, and have since won fame by their contributions to the knowledge of electricity, it does not become me to describe the Exhibition, or to comment upon its influence. Fortunately for the success of this meeting, and for the fame of the Institute, there are men present, distinguished in your science, who can appropriately do this.

"Your industry, which had its beginnings within my generation, and has grown with unparalleled rapidity, offered opportunity for the exercise of the highest talents of men with combined engineering and administrative ability. The gentleman who is to make the first address this evening has given ample evidence, during the last thirty years, of possessing engineering

ability of a high order. The position that he holds to-day is proof conclusive of his possession of administrative and executive ability. I have great pleasure in introducing Mr. E. W. Rice, Jr., president of the General Electric Company."

MR. E. W. RICE, JR.: "Ladies and gentlemen, when I was asked by your chairman to come here to-night and make a short address in commemoration of this anniversary, I hesitated. It seemed to me that thirty years, a long time in the history of our industry, was so long that I could hardly trust my memory as to the events which occurred at that remote time. I also hesitated because I had a natural reluctance to appear to be such a patriarch in the business as to have recollections of such, I may say, almost prehistoric times.

"However, I consoled myself by thinking that I could supplement my recollections by my imagination, but even that refuge has been destroyed, as your committee has brought here as witnesses men who were the mighty creators of our industry, men who were producing, inventing, and starting this industry when I was but a mere boy. There is no danger that their memories may be as accurate, as true, and as remarkable as their deeds, and I shall have to confine myself, therefore, rather closely, I fear, to the facts. In the invitation which your chairman sent to me, he made some complimentary remarks to the effect that I had taken a prominent part in that exhibition. I suppose that this conclusion came from the fact that he may have found my name associated with that of Professor Thomson in connection with the exhibit of the Thomson-Houston Company, and also that my name was upon the list of the conferrees of the International Conference of Electricians, which was held concurrently with the Exhibition. However, at that time I was so young—in fact, I think about the only honor I can claim in connection with that conference, perhaps, is the somewhat doubtful honor of being the youngest conferree. I plead, however, in extenuation, that I was a good boy and was properly 'seen but not heard.' It is rather difficult, even for those who have lived in those times, to look back and properly picture to themselves the conditions of our industry at that remote period.

"At that time there was not a single trolley car in operation anywhere in this city or in the country, or, so far as I am aware, throughout the whole world.

"The highest voltage that was used commercially (I will ask Mr. Brush to correct me if I am wrong) was about 2000 volts. The largest current that was mentioned—and this was only mentioned by the scientists of the conference, and mentioned with bated breath, as if it were something to be hoped for, the ultimate attainment—was 5000 ampères. The largest electrical generator was the Edison Jumbo, which was capable of operating, I believe, 1200 16-candle-power lamps. The largest engine prime mover was under 200 horse-power—I think under 150. I am speaking now of what was at the Exhibition. This was long before the days of the X-rays, of course; of automobiles and of flying machines.

"I sometimes think that the gospel of work was somewhat more popular, and it was necessary to bustle a little more than it is to-day, when some people seem to get along with talking a little, and with the policy of waiting and watching. That, however, has not yet afflicted our industry.

"My mind naturally runs to some of the old stories which were circulated in those days—naturally they were childish as the industry was young—the old pioneers well remember them, and perhaps some of you gentlemen may, but, at any rate, I hope you will forgive me for recalling them.

"One that was quite popular related to a shipment of a dynamo. One of the large manufacturing concerns had shipped a dynamo to an important customer, and sent a letter saying 'I am shipping you a dynamo with 200 volts.' And the reply came back, 'We have received the dynamo, but where are the volts?' That is a companion story to the one about receiving lamps without the 'currents' and without the 'watts' and few things of that kind.

"But I am rather digressing, and I will try to describe briefly some of the things which we exhibited. First, I will say something about the exhibit in which I was interested, that of the Thomson-Houston Company, with which I was associated. Our principal exhibits naturally consisted of several sizes of Thomson-Houston arc dynamos, arc lamps, and various fixtures which went to make up a system of arc lighting in those days. I quote as follows from the complimentary reference to our exhibition made in the General Report of the Chairman of the Committee on Exhibitions:

"'No company presented a more systematic display of electric lighting machines and accessories than the Thomson-Houston Company, and it was particularly valuable from an educational point of view. The exhibit had been carefully set up in Lynn before it was brought to Philadelphia, and throughout gave evidence of the conception of a perfect organizer. Some of the instruments, with mechanism dissected, illustrating the principles involved in working their machinery, and the large solenoid showing curious magnetic effects, were the source of continued study by amateurs.'

"The following is a rather incomplete list of some other exhibits which our company made:

"Thomson film cutouts;
"Thomson vacuum cutouts;
"Thomson lightning arrester for dynamos;
"Special galvanometers for electric light circuits;
"10-ampère arc-light circuit divided into two circuits with two series of arc lights of 5 ampères each;
"One motor dynamo;
"Small electric motor;
"Incandescent distributers for arc-light circuits;
"Thomson combined motor and alternating-current dynamo.

"The above list is of interest as indicating the activities of one of the leading companies of those days. Motor-generators, especially direct coupled motor-generators, were then a great novelty, and one of the two motor-generators which we exhibited was a direct-current motor coupled directly to an alternating-current generator.

"Lightning arresters for the protection of electric-light circuits were, I believe, introduced in the art by Professor Thomson, and at this time were quite a novelty.

"The film coutout mentioned was the forerunner of the film cutout which has been so universally used on series incandescent lighting circuits.

"The division of the 10-ampère arc-light circuit into two independent series circuits of 5 ampères or split circuits, a large electro-magnet or reactance coil, which showed a clear recognition on the part of Professor Thomson of the properties of reactance in an electric circuit, and was probably the first application of such a principle for such a commercial purpose. It

naturally attracted a great deal of attention. It is unnecessary to state that such a division of the electric circuit would not be possible without the use of reactances or large resistances.

"The electric motor was just beginning to be used commercially at the time of The Franklin Institute Exhibition. In addition to the motors which we exhibited, the Brush Company had three in operation, one running two looms and one driving a plating machine and one driving a fan for ventilating the general offices of the Exhibition. Almost all the large electric companies had one or more electric motors on exhibition.

"I particularly remember the exhibit of Frank J. Sprague, who showed a number of electric motors arranged for constant potential circuits which gave constant speed under variable load without any automatic regulator. Some of these motors had in addition to the regular shunt winding a few series turns arranged for differential action, the effect of which was to weaken the field just enough to give constant speed under the most extreme variations of load. I was very much impressed with the behavior of these motors and with the ingenuity of the method adopted by Sprague to produce a variable load. As indicating Sprague's enthusiasm and prophetic vision, I would also mention that he exhibited a motor for electric railway purposes with self-contained means for varying the mechanical effects as speed and power, and means for reversing the direction of rotation: this at a time when two principal railways of Philadelphia, the Union and Market Street Lines, were at work changing their entire system of something like twelve miles from horse cars to the cable system, and it was naturally several years before the famous Richmond installation or Van Depoele's first electric trolley installation at Toronto.

"Probably the most impressive exhibit was that given by a combination of the six companies operating at that time under Edison's patents. This exhibit occupied a large space and showed the Edison incandescent lighting system, a large Jumbo dynamo, and a particularly prominent feature was a pyramid 30 feet high, containing some 1200 Edison incandescent lamps, which attracted great attention when lighted, as it was at regular hours.

"In this connection I will risk another old story. A lady had just finished reading an account of the Edison display, when she laid down the paper with an expression of horror and said,

'I see that Edison is going to put in a thirty-ton dynamo; I don't think that should be permitted.' After meditating awhile, the danger seemed even greater, and she exclaimed, 'Suppose some horrid fellow should throw a lighted cigar into this; why, thirty tons of dynamite would blow up the whole city!'

"I remember with interest that organ recitals were given at intervals upon an organ, the bellows of which was driven by an electric motor, and the pipes operated from a considerable distance through the medium of an electric keyboard.

"The United States Electric Light Company exhibited a system which was largely representative of the genius of Edward Weston. This consisted of dynamo machines for arc and incandescent lighting, arc lamps, incandescent lamps, motors, instruments, etc.

"In the Brush exhibit were shown not only the well-known Brush arc lighting system of dynamos, arc lamps, etc., but also the Swan incandescent lamps, and what was then a great novelty, the Brush storage battery. This was about the first bow for commercial favor of the storage battery in America.

"Other well-known pioneers of the early days were there in great numbers, such as Van Depoele, Ball, Bernstein, Hochhausen, etc.

"In addition to the exhibitors of electric light and power apparatus there was also a very interesting exhibit by the Western Electric Company of switchboards, magnetic call bells, cables, telegraph and telephone apparatus. The American Bell Company had a working telephone exchange system connecting with the exhibitors and all the subscribers of the Philadelphia Exchange, and a particularly interesting historical exhibit of the first telephone, the telephone of Bell exhibited at the Centennial Exhibition, carbon transmitters of Edison and Francis Blake, and the original telephone exchange switchboard.

"The *Electrical World*, which was then in its infancy, had the great enterprise to print its weekly edition during the Exhibition by a press run by a small Daft electric motor, and claimed, and doubtless with its customary accuracy, that it was the first time that any journal was regularly printed by electricity.

"However, my most vivid memories of this time were not of the buildings, machinery, and exhibits, but of the men, the great inventors, scientists, and the pioneers of those days, many

of whom have since passed away. I remember especially the meetings of the Conference of Electricians, the most commanding figure being that of Lord Kelvin—Sir William Thomson, as he was then known. At these meetings I had the great pleasure to listen to such men as Sir William Preece, Sylvanus Thompson, Simon Newcomb, who called the Conference to order and introduced the president of the Conference, Prof. Henry A. Rowland. I remember how thrilled I was by Rowland's opening address. Lord Kelvin, who followed, called Rowland's address 'an admirable exposition of the relations between pure science and the application of science to the wants of men.'

"The Conference which followed was, as I have stated, presided over by Professor Rowland, and was participated in by Lord Kelvin, Sir William Preece, Prof. Sylvanus Thompson, Prof. John Trowbridge, Prof. George F. Barker, Prof. Wm. A. Anthony, Prof. Elihu Thomson, Prof. Simon Newcomb, Mr. Frank J. Sprague, Mr. Nathaniel Keith, Mr. Thos. D. Lockwood, Prof. George Forbes, Prof. E. J. Houston, Prof. Alexander Graham Bell, and many others.

"Its most important work was the recommendation of the recognition by Congress of the ohm, the ampère, and the volt, following the Paris Conference. After this Professor Rowland read a long paper on the theory of the dynamo electric machine, full of valuable advice; it contained information and views much in advance of the times, and was not, I fear, fully understood. However, it contained definite and rather sharp criticisms of many designs which then existed, and provoked, as a consequence, a lively and at times a warm discussion by the various inventors who felt that their pet designs or theories had been criticised.

"A most interesting discussion followed the recommendation by Sir William Preece of the adoption of the 'watt' as the unit of power, and a further amplification of Sir William Preece's suggestion made by Professor Cress to call one thousand watts a 'kilowatt.' The term 'watt' was finally adopted by the Conference, but the adoption of the 'kilowatt,' while favorably considered, was postponed.

"I think the Exhibition and Conference had a wonderfully stimulating effect upon the design and manufacture of electrical measuring instruments of various kinds. The subject was most intelligently discussed by the Conference in establishing the ohm,

volt, and ampère, and considerable time was devoted to the discussion of the necessity of improved instruments and better methods of calibration.

"Sir William Preece said, speaking of the need of the greater accuracy of measuring instruments, that 'I tried instruments from every maker known to be fairly accurate, yet I scarcely succeeded in obtaining instruments to record to an accuracy of five per cent. It was a common thing to find our ampère metres showing an error of ten per cent., but the volt meters were more accurate. At the present moment I do not know of a single instrument in England that can be bought from an instrument maker that has recorded upon it a certain scale that can be relied upon to within five per cent.'

"Sir William Thomson, speaking upon the same subject, stated that 'we have at present ampère and volt meters which are not good even within two or three per cent., and sometimes not within ten per cent., of what they profess to be. There is a great difficulty in obtaining instruments which have the conditions of constancy in themselves, and when any one has prepared an instrument which has in itself the conditions of constancy it is exceedingly difficult to get the value of its coefficient determined.'

"The scientists and practical workers in the electrical field at the Conference all felt the need of accurate, rugged instruments which would permit the accurate and speedy measurement of the various electrical quantities. How well the demand was met, particularly by Edward Weston, is a matter of history. I have always believed that the electrical industry owes much of its wonderfully rapid advancement to the accuracy and quickness with which we have been able to measure the various electrical quantities. Indeed, one has only to think of the time, expense, and difficulty incurred in making any other measurement, particularly of a mechanical nature, such as the measurement of the power consumed by a machine or the flow of steam or water, to realize the debt which we owe to electrical instruments. Indeed, the easiest and more accurate method of measuring mechanical power is now indirectly by electrical means.

"I may be pardoned, perhaps, for saying that one of the most pleasant recollections which I retain of The Franklin Institute Exhibition is that three of my professors at the Central High School took such a prominent and important part in the work of

the Conference and of the Exhibition. Professor Houston was the Official Electrician of the Exhibition and Chairman of the Committee on Electrical Installation. Professor Snyder was Special Chief of Measurements, Testing, and Reports, and Chairman of the Committee on Conferences. They were both members of many other committees, and took a prominent part in the Electrical Conference. A very notable address was also made by Professor Snyder, recommending the establishment of a National Bureau of Standards adequate to the scientific and practical needs of the nation. Professor Thomson was the chief inventor of the Thomson-Houston Company, one of the exhibitors, and was also a member of the Conference of Electricians, and took a prominent part in its discussion.

"Professor Thomson, writing recently respecting the Exhibition, states that 'The Franklin Institute Exhibition was the first exhibition in the country to be devoted to electricity alone, and during its continuance the first Electrical Conference came off. The Exhibition itself, as you will remember, was a unique collection of exhibits, showing practically the status of electrical work at that time in a fairly complete way, and the Electrical Conference referred to came at a time when great interest was being manifested all over the world in the future development of electrical applications.'

"One of the most remarkable features of The Franklin Institute Exhibition, which is perhaps unique in history, is that 'the report of the Treasurer showed the Exhibition to have been a financial success. The entire expense of the erection of buildings, the cost of shafting, steam piping, as well as the running expenses, were promptly met' and a 'balance of some $10,000 to $20,000' left in the Treasury. 'This was accomplished without Government aid or the use of public moneys.' In view of the fact that the Exhibition was in every other way a great success, the financial record is certainly refreshing and tempts one to believe that perhaps after all they knew how to do things better in some respects in the good old days."

DR. WALTON CLARK: "Before the Exhibition of 1884, and for a hundred and thirty-five years previously, when 16-candle coal gas was a luxury, sold, perhaps, at $2.50 a thousand cubic feet, but little used, sales per capita of 700 or 800 feet, we did not appreciate the influence and the value of bright lights, we did

not know that there was an arc light, and we did not know that a light equivalent to an arc light was as good as a policeman; in reality, we did not know what could be done for the protection of property and of innocents in our cities, until the gentleman who will speak next brought out his machine and his lamp. I do not know as much of the subject as you gentlemen do, but I know something of it, and I believe firmly that no man since the world began has done more for the protection of person and property in the great cities than Dr. Brush, whom I now have the pleasure of introducing."

DR. CHARLES F. BRUSH: "Mr. Chairman, ladies and gentlemen: When, two or three weeks ago, I was invited to come down here on this occasion and say a few words, I did not hesitate, as Mr. Rice says he did, but I promptly declined. Some of my friends were so good as to point out the pleasure that I would forego, and other considerations, and I consented to rearrange previous engagements, came down, and here I am. I will comfort you with the statement that I am not going to give you an address. I have endeavored to-day to ascertain from my friends what they would like me to say a few words about, but my efforts have been quite unavailing: they have not given me any hint. But we know we are commemorating the electrical exposition of 1884. That has been spoken of already, and, as most of you know much of the history of the development of the great electrical industries since that time, it occurs to me that perhaps I would better say a few words of the earlier history of these great industries which we are so familiar with to-day, especially because that may be summed up briefly, while their history since that time might well fill a library of many volumes.

"In speaking of the early history of electrical development in this country I cannot avoid being personal to some extent, and I hope you will pardon that, because at the time I became interested in the subject it was not much of a subject, and there were very few thinking of it, and any one who happened to take an interest in it was conspicuous for that reason, and could not say anything about it without being more or less personal.

"As this is partly a function of The Franklin Institute, too much cannot be said for that venerable and splendid institution. I think we may safely say that, in a way, the electrical industries as we know them to-day were born and fostered in that institu-

tion, and I have particularly in mind the year 1877, when the Institute became ambitious to own a dynamo electric machine, a thing very rare in those days, and invited such makers as there were in the world to send in their apparatus and compete for the sale.

"Professors Thomson and Houston, if I remember correctly, took entire charge of the electrical measurements, which extended over a period of several weeks, and the contest excited in Philadelphia great interest, and I think it may be justly said that the interest then aroused here and elsewhere indirectly started the growth of our great industries.

"That was in the summer or autumn of 1877. In the spring of 1878 there began to be some little indications of commercial activity in the field of electric lighting, and by the summer or autumn of 1878 there was considerable activity in this field; and it is interesting to note that a Philadelphian, Mr. John Wanamaker, lighted his great store almost wholly with electric arc lights. He had a plant by the autumn of that year, consisting, I think, of 20 arc lights of about the present size. That was far and away the largest electric lighting plant in the world, and it was in Philadelphia.

"Of course, some humorous things occurred in the early days of the industry. I remember one occasion when a small electric light plant, perhaps a 20-ampère light—which was large for those days—was shipped to Cincinnati by the then Telegraph Supply Company, to Dr. Longworth, an enterprising scientist of that city, and I went there to show him how to run the lamp. It was exhibited in front of the building in which he had his office, and, of course, attracted a great deal of attention. On the first evening when it was shown a large crowd of the natives gathered in front of his establishment, and you could hear various exclamations of delight. Here and there in the crowd you could hear some one person delivering a little impromptu lecture on the electric light, and he would have quite a hearing. You may, some of you, recall that in these early days the lamp that first made its appearance had a large solenoid at the top, through which ran a rod which carried the carbon. One man who had collected quite an audience pointed to the solenoid and said, 'Gentlemen, that is the can that holds the oil.' The lamp had two rods at the sides. He pointed to them and said, 'Those are the tubes which convey

the oil from the can to the lamp.' He created quite a sensation, and his hearers went away feeling that they knew a whole lot about the electric light, although the speaker had said nothing about it at all.

"In the summer of that year an exhibition was held at the Union Steel Screw Works in Cleveland. A dynamo was exhibited there which operated four electric lights on separate circuits with the non-series lamps, and quite a large company of invited citizens was present to witness the exhibition. One of the most prominent of the old Clevelanders seemed to be greatly interested, and he pointed to the line wire between the lamps, which was bare copper then, and he asked me, 'How large is the hole in that little copper tube through which the electricity passes?' He was quite in earnest.

"The superintendent of the shop, one of those men who knows everything, looked for five minutes, perhaps, at the dynamo. There was more or less sparking on the commutator, as there always was on electric-light dynamo commutators, and then he was ready to tell me all about it. He said, 'The electricity in that thing is generated by that revolving business rubbing the air up against them iron blades,'—he called them, meaning the pole shoes of the magnets,—'just like you get sparks when you rub a cat's back.' I said this was a simple and beautiful theory, but it was not entirely right. However, that did not affect him at all. He said, 'It is perfectly clear; if you should run that thing in a vacuum, you would not get any electricity.' He seemed to be so happy in his state of mind, in his theory, that nothing further was said about it.

"Late in the fall of 1878 there first appeared the device known as the series arc lamp, and I think we may call that year, 1878, the banner year in the early history of the electrical industry, because it was that device which first made electric lighting from central stations commercially possible; I think we may regard that year as marking the birth of the electric lighting industry. Prior to that time the development of electric lighting was slow, but after that it was very rapid, and as early as the spring of 1879 the public square, a little park of about ten acres, in Cleveland, was lighted with twelve series arc lamps, and it has been lighted electrically ever since. I am quite sure that was the first electric street lighting in the world, on a commercial basis. And

that is not so very long ago—that is, it does not seem so to me, but it will to some of you. I was introduced a week or ten days ago at the opening of an electrical exhibition in Cleveland by a chairman who said he had the pleasure of introducing a gentleman who was familiar with the electrical industry in 1779. I promptly claimed an alibi before any one had a chance of asking me if I remembered the true inwardness of the Washington-hatchet story current at that time. I got in ahead of them; I wasn't asked.

"It is interesting to reflect that even at that time, 1879, when the industry had really made a start, we had no shop instruments such as we have now—no ammeters, voltmeters, and so on. We had to guess at almost everything. It was about 1881 when we first had instruments of that nature.

"Many references have been made to the electrical exposition that we are celebrating to-day, but it was my good fortune, my privilege, to attend an electrical exposition in Paris in 1881, which was perhaps the first of its kind in the world. It was held in the great Palace of Industry there, and was considered a great affair at the time, and it was. But while that was very early, I think we may say that most of the seeds of the great industries which have developed since were there. There were perhaps 100 arc lights and about as many incandescent lights, and all were used to light that great building, and it was thought they did it splendidly. And there were various types of dynamos, both alternating current and direct, and a few motors. And there was the telephone, of course. That was just beginning to attract great attention, and there was a crude form of storage battery which excited very much interest. There was a real trolley car, which ran a few hundred feet back and forth outside the building—when the electrical conditions were propitious—which was not very often—and it was always crowded with passengers, many of whom had waited a long time for a chance to get aboard—quite like the present-time practice.

"Going back a moment to the year 1878, which, as I said, was the birth year of our great industries, the year from which they started a vigorous growth, I imagine there was not invested in the whole of the electrical industries more than two or three hundred thousand dollars. I think that would be ample to represent them all, outside of the telegraph. In 1905, which was

27 years later, I had occasion to collect some data as to the amount of capital invested in the electrical industries at that time, and to my surprise I found it to be not less than four thousand million dollars in this country alone; that is about one hundred and fifty million dollars a year on an average, for the 27 years, or half a million dollars for every working day during the 27 years. Now, in the nine years since 1905, I imagine the investment has been, on an average, three times as rapid. I think we are within bounds in estimating that for the last nine years there has been something like a million and a half dollars of new capital going into the electrical industries every working day of that period; and the end, gentlemen, is nowhere in sight. I am glad it is not, because those who can will have the pleasure of seeing them develop, perhaps even more rapidly than we have. I know the hour is getting late, Mr. Chairman."

THE CHAIRMAN: "You have an all-night license."

DR. CHARLES F. BRUSH: "No, I don't want to talk all night, I did not intend to talk at all. Thank you, gentlemen."

THE CHAIRMAN: "The electric machine that Dr. Brush speaks of as having been sent to The Franklin Institute is now on the floor. We have always been glad it was not larger, because one day the current from that machine went through Elihu Thomson, and he fell to the floor.

"Many of us, those of us who are gray here, remember the single horse car that went 'jog, jog,' across the country, and we can compare its slow rate of progress, the few people it carried, with the present rapid transit between cities and to cities, but we owe it to men, one of whom is with us to-night, and who, I hope, will tell us what influence the Exhibition about thirty years ago had on the electrical trolley business. I have great pleasure in introducing to you Mr. Frank J. Sprague."

MR. FRANK J. SPRAGUE: "Mr. Chairman, ladies and gentlemen: I am going to talk less than most of my predecessors. I know that will be the most welcome news that I can give you. In fact, I begged to be excused entirely, because as I looked to the other side of the platform and saw that patient, grand old man of our electrical profession who once unceremoniously fired me, and afterwards was present at the award to me of the Edison Medal, and who, I know, while sitting there very patiently, is hoping this meeting will come to a close, I am reminded of a

little incident that happened on that aforesaid occasion. Tom Martin said to him, 'Did you hear any of this?' 'Not a word.' 'You must have enjoyed yourself.' 'I always do when I think by myself.'

"As I look about this association and see the representatives of that great industrial fabric which is misnamed the National Electric Light Association, I am reminded of the fact that it ought to be named the National Electric Light and Power Association, because it was predicted by those who interested themselves more particularly in power some years ago that our great central stations must become diversified suppliers of electrical energy for every purpose, and in time the demands for power would outpace that for electric lighting. I believe I am safe in saying that already in Chicago, possibly in this city, and in New York even now, the capacity connected up for power purposes is greater than the enormous total used for electric lighting.

"Your industry has been founded partly upon capital, but largely upon the efforts of inventors and engineers. Few inventions are the result of inspiration. They are simply engineering developments brought out at such period in answer to some impelling demand. It is said that necessity is the mother of invention. If that were a recent expression I think we could charge that phrase to the militant suffragists or the feminists. I hope, ladies, there are none of the latter in this audience, as the feminists have been defined as that class of individuals who hope for free love in a manless world.

"In this connection I am reminded of a far-away Indian tribe, visited by a man well known to most of us, Oscar T. Crosby, who resigned from the army to become associated with me in the construction of electric railroads in the early days, where a peculiar habit, the complement of polygamy, polyandry, exists. For economic reasons, the inheritance of land, or whatnot, marriage is somewhat limited in degree. The eldest of a family of brothers, taking unto himself a wife, shares his privileges with his younger brothers. If necessity be the mother of inventions, it is polyandrous, because here and there throughout the world there often appears the same invention, and, as in the case of this tribe to which I have referred, if the child is one which is sufficiently attractive, we find that there are many parents claiming paternity for it, irrespective of the facts. Most

of us are inventors, engineers, or electricians, or what-not, partly because of environment and partly because of the early conditions in which we were placed. It was my good fortune to graduate from the United States Naval Academy in 1878. I hesitate to go back a third of a century; it doesn't look so long backward, but it is a devil of a distance ahead, and I remember the rise in the firmament of the names of Edison and Gray and Brush and Bell, which fired my young imagination. One day I wrote to Edison: 'May I stop and see you at Menlo Park? I want to show you an invention.' He replied favorably, and so I came to him with an invention of a telephone. He looked it over, criticised it somewhat, made a few rough sketches of a somewhat better plan, and I suddenly lost interest. He said, 'If you don't think I am right, go up in the laboratory and try it yourself.' I went up stairs, but after I had been there ten minutes I had forgotten all about the telephone, and was intensely interested in an incandescent lamp which Edison was developing. Later I went on a tour around the world, but I never lost sight of that vision of the coming electrical power, and I planned to leave the naval service. Finally I did get home in 1880 for my examinations, and I was delegated for service on a training ship to teach young ideas how to shoot, but I still thought of that electric light, and I said to myself, 'What a great opportunity this is to introduce it into the navy!' You know that then we midshipmen slept in hammocks and used tallow candles. I went down to the engine room and, casting my mechanical eye around, discovered an old single-acting steam pump for supplying the boilers, with a flywheel, a water cylinder at one end and a single steam cylinder at the other, and I thought to alter that pump into an engine that would light the ship. I sent to Edison to see if I could get hold of one of his early dynamos, as I wanted to try to light the *Minnesota* with electricity. He sent back word, with that horse-sense of his, and said that engine I wanted to use would run that dynamo so irregularly that the electric light would be damned forever on board ship.

"Two years afterward, in 1881–2, it was my privilege to be ordered to the second electrical exhibition which had been held; the one that Mr. Brush spoke about was at Paris. This second one was at Sydenham, the Crystal Palace, and there I became absorbed in admiration of the work of Mr. Edison, represented

at that time by Mr. Johnson. There was a battery of twelve machines, arranged in three groups, and requiring a total of about 100 horsepower to drive them. Remember that this was only thirty-two years ago, and to give you some idea of the advance from that date look to the electrical plant in this city, where you are now installing a single turbine unit weighing 600 tons, with a normal capacity of 35,000 kilowatts, nearly 7000 times larger than the unit machine shown by the Edison Company at the Sydenham Exhibition in 1882.

"It was my pleasure at that time to report to the Navy Department in these words regarding the Edison system:

"'In the matter of making transmission of light and power a practical success, and bringing it home to everyday domestic economy, Mr. Edison, without doubt, has done more than all others.'

"But at this Exhibition there was not an electric railway, there was not an electric motor of any kind or character. There was no suggestion of anything, in matters of that kind, except the electric light.

"In 1884 came your Exhibition here in Philadelphia, and the only electric railway that was here was a small model railway put in by a Mr. Bidwell, I believe, deriving current from a brush passing through a slot, and operated within the building, and two years later, in Boston, New York, Philadelphia, and Baltimore, I was operating experimentally single electric cars with storage batteries.

"Van Depoele, now passed on to the beyond, and Leo Daft, who is still with us, had also become active, and it was my pleasure, in 1887, to inaugurate the pioneer modern Richmond trolley railroad, with what consequences in this art you now know.

"It has been stated that there was loom driving at this Exhibition. I have in my hand a cut from the first piece of cloth woven on a loom driven by a constant speed, non-sparking, constant potential motor, one of my earliest productions.

"The path of those who were active in the early developments has not always been an easy one. I remember some twenty-three years ago, prior to the introduction of the multiple-unit system in the operation of railways, and prior to determining what would be done on the subways of New York in

rapid transit, in order to overcome the activities of the elevated railroad owners in the city of New York, backed by newspapers of that city, and to prevent the extension of elevated railroads, I took it upon myself to publicly offer, at the expenditure of $50,000, to put two electric trains in operation on the elevated railroad, one to be operated by a locomotive and one by motors under the cars, at speeds of forty miles an hour. This was intended to demonstrate that the first thing to be done in determining rapid transit was the acceptance of electricity as a motive power, but it took the rapid transit committee of that city many years to come to that conclusion. I know I attempted in 1886 and 1887, and then again in 1896, to interest the elevated railroads of New York in electrical operation. I twice offered, at my own expense, to make a demonstration of the multiple-unit possibilities with a full six- or eight-car train, but it fell upon deaf ears, and it was not until two years after such offers that the opportunity came commercially to make the first introduction of that system.

"One of the great ambitions of all of us has been to electrify the railroads of the world, especially the trunk line railroads. It has been a common prophecy of electrical engineers that main line railroads would be early electrified, and the steam locomotive thrown into the discard. Hopes have outpaced facts, for when the gilded electric giant—and gilded it must be because of the large amount of capital required—goes into the arena to meet its iron-clad opponent, the modern locomotive, on the basis of comparative economy of operation and capacity, it has been a hard row to hoe.

"In the urban, suburban, and interurban fields, and now also in terminal operation, electricity holds its own, because it deals with classes of traffic often impossible for like operation by steam; but when we get into the trunk line operated field we must then discard a great deal of existing investment, and must incur large investments at a time when money is very difficult to raise.

"Now, how is the advance going to be made? Right with you, gentlemen, lies in a great measure the solution of that problem, for the matter of supply is more important than the question of system. Engineers have racked their brains and hoarsed their throats in arguing the merits or demerits of single and polyphase and high and low tension direct currents, but I tell you

that neither one of these questions is so important as the question of power supply.

"Every one who looks forward to the future of our country sees a spectre arise. What is it? The failure of our coal and timber supply, and the necessary consequences. With an ever-increasing demand for power, we must then fall back upon water and hydraulic power, but meanwhile we must conserve all we have. Mr. Insull has spoken of the limitation which may be imposed by law upon normal development. You can no more stop the extension of electric lines from one State to another than you can stop the travel on a country road, no more than you can put bounds upon agricultural fields, no more than you can dead-end the rails of a steam railroad. The small power plant must disappear, great power plants, properly located, must be erected and connected together by lines which are absolutely protected. In the end, these connections will be underground, not overhead, for protection against accidents to the public, for the same reason the Bell Telephone Company runs its lines from Boston to New York underground instead of overhead. Now, when that time comes, since the demands of the electrified railways will be so small in comparison with the aggregate diversified demands upon power plants, the steam railroad man no longer can say: 'Reliability cannot be had except under our supervision and control; economical production of power cannot be had except under our management.' Then they must acknowledge, as it is typified in Chicago, and here and elsewhere throughout the country, that the central station can often supply to a steam railroad power for their purposes in whatever needed quantity with greater reliability and at less cost than the railroad can create it for itself.

"So in time we will have electric railways upon our trunk lines, but it is to you we must look rather than to the disputants as to system. The natural power lines are the rights of way of the railroads themselves.

"I was asked if I had any prophecy to make to-night. I have, and I do not hesitate to make one. Electricity is going to also help the operation of our trunk lines in a somewhat different way. In the United States there are not less than four hundred and fifty thousand to five hundred thousand miles of single-track trunk line operation, and over those are propelled millions of tons of freight and millions of passengers under the control of great

power units, governed by intelligent engineers, backed by efficient braking systems. In front of every one of those engineers is a signboard at every block which says in effect: 'Keep off the grass because it is fresh,' or 'Here is danger.' It is called a signal. On four-fifths of the railroads of the United States it is manually operated, but on the other one-fifth it is set and cleared by the trains as they pass. Every now and then a horrible accident occurs. Why? Because, according to the reports of the Interstate Commerce Commission, there is no reliable connection between that signboard and the man who runs the train. Now I will make this prediction: That long before our main railroads are operated by electricity we will materially increase their safety of operation by tying the signboard and the engineer on the locomotive together electrically, so that the man, who, whether from failing eyesight, adverse weather conditions, momentary inattention, or whatnot, loses for a moment a knowledge of the conditions in front of him, the human freight behind him will not go pellmell into a collision, for the track conditions will be signalled into the train, and it will be braked and stopped in case the engineer fails to exercise the attention which is his duty. That is the prophecy.

"Just a final word: We are not all of us engineers, and are not all commercial men, but there is at least one thing we can be proud of: we belong to that industrial profession which has done more for the safety and for the comfort of the world than all which preceded it, which represents typical American progress, which represents modern industry, and conveys the hope of the future to our posterity.

"Gentlemen, I thank you."

CORRESPONDENCE.

RAVENNA, OHIO, May 29, 1914.

DEAR DR. OWENS:

Yours of the 25th inst., inviting me, on behalf of the National Electric Light Association and The Franklin Institute, to be present at a celebration of the Thirtieth Anniversary of the 1884 Electrical Exhibition of The Franklin Institute and the National Conference of Electricians of the same year, held under its auspices, is at hand. I regret to say that illness in my family, together with a disinclination to make a long journey at this time of the

year, which is doubtless to be charged to "advancing years," compels me to decline the very kind and very tempting invitation, which I do most reluctantly. I am sure the occasion will be of great interest to those who are present, and especially to the rapidly dwindling group of "old-timers" who were on the "skirmish line" a third of a century ago, when, as we were accustomed to hear and say *ad nauseum*, "electricity was in its infancy."

Thinking that there may be something of a historical exhibit in connection with the proposed celebration, and not being able to go myself (though I would be, if present, only an insignificant item in such an exhibit), I am sending you by Adams Express to-day a document which I believe will be of interest to all electricians, whether of the young or the old generation. It has no direct connection with the Exhibition or Conference whose anniversary is to be celebrated, but with the International Congress of a few years later, which was itself, in large measure, an outgrowth of the 1884 gathering. As the original and first record of the definitions of the fundamental units of electrical measurement unanimously adopted by the International Electrical Congress of 1893, and, within a year, enacted into law by the Congress of the United States, thus furnishing a basis on which a business involving many hundreds of millions of dollars has been successfully developed during the last quarter of a century, it is, I think, well worthy of preservation in the archives of some institution like The Franklin Institute or, possibly, the American Society of Electric Engineers. Its history is as follows:

On the afternoon of August 23, 1893, the "Chamber of Delegates" of the International Electrical Congress in session at Chicago began the serious consideration of the definitions of the ohm, ampère, and volt.

Speaking for the American delegates in the Chamber, I had submitted a draft of these definitions upon which the Americans were agreed. There was a long and by no means harmonious debate upon this draft, in which it received the approval of the English delegates but it was opposed in certain particulars by the representatives of Germany and France.

The discussion was not free from a tendency towards national prejudices and animosities, and at one time threatened to interfere with the working of the Chamber to such an extent that it might fail in the accomplishment of the object for which its delegates had assembled from all of the principal nations of the world.

At a late hour it was agreed to refer the whole matter to a representative committee including delegates from England, France, Germany, and the United States, which committee was to report to the Chamber at its next sitting on the following afternoon. This committee, as chosen, consisted of Messrs. Von Helmholtz for Germany, Ayrton for England, Mascart for France, and Mendenhall for the United States, together with the President of the Chamber of Delegates, Professor Rowland, as *ex-officio* member. Late that night, in my room at the hotel, having in mind the criticisms and objections that had developed in the prolonged discussion of the afternoon, I made another draft with pencil on the leaves of a "pad" or tablet of yellow paper that happened to be at hand. In its preparation I tried to avoid both the Scylla and Charybdis upon which wreck had been threatened, and when I submitted my memorandum to the other

As a unit of resistance the International Ohm, which is based upon the Ohm equal to 10^9 units of resistance of the C. G. S. System of electromagnetic units and is represented by the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice 14.4521 grammes in mass of a constant cross sectional area and of a length of 106.3 centimetres

As a unit of current
the International Ampere
which is one tenth of the
unit of current of the C. G. S
system of Electromagnetic units.
and which is represented
sufficiently well for practical
use by the unvarying current
which, when passed through
a solution of nitrate of silver
in water in accordance with
accompanying specification
deposits silver at the rate
of 0. 001118 of a gramme
per second.

As a unit of Electro motive
force the International volt
is the electromotive force that
when steadily applied to
a conductor whose resistance
is one International ohm will produce
a current of one International ampere
and which is represented sufficiently
well for practical use by $\frac{1000}{1434}$
of the Electro-motive force between
the poles or Electrodes of the
Voltaic Cell known as Clark's
Cell at a temperature of 15° -
and prepared in the manner
described in the accompanying
Specifications.
E. Mascart v. Volumbo
H. A. Rowland F. C. W. Arptin
T. C. Mendenhall

members of the committee at its meeting on the following morning it was found to require only two or three slight verbal alterations to meet with the approval of all. Where these changes were made may easily be seen at the present time. Just as the committee was about to adjourn it occurred to me that it might be well to insure against possible subsequent change of opinion by having the memorandum signed by all of the members, and a suggestion to that end was cheerfully accepted. A "clean copy" was submitted to the Chamber as the committee's report on the afternoon of August 24th, and after very little discussion was unanimously adopted by that body.

The definitions of the three fundamental units thus adopted, together with other units subsequently approved by the Chamber, were officially accepted by the Superintendent of Weights and Measures at Washington, and, with the approval of the Secretary of the Treasury, were promulgated in Bulletin No. 30 of the U. S. Coast and Geodetic Survey, of which bureau the office of Weights and Measures was at that time a "Division." This immediately affected all government contracts in which electrical measures were involved, but an act of Congress was necessary to make the use of the units compulsory throughout the country. With the advice and assistance of the Chairman of the Committee on Coinage, Weights and Measures of the House of Representatives, the Hon. Charles W. Stone of Pennsylvania (who exhibited a most active and intelligent interest not only in this but in all the legislation affecting weights and measures), I drew the bill which was enacted into law and received the approval of the President on July 12, 1894. This law was proclaimed in Bulletin No. 31 of the U. S. Coast and Geodetic Survey, a copy of which I enclose herewith.

You will note that the law is almost word for word a copy of the memorandum which I am sending you—a few verbal changes having been made, mostly, as I remember, at the suggestion of Mr. Stone, to shorten the phrases as much as possible without affecting their meaning in any way.

Some time after the ending of the International Congress, finding this rough draft among my papers and recognizing its historical interest, I had it put in a frame for preservation as it is to-day.

For several years I have been the sole survivor of the "signatories" and, as the little document seems to mark the beginning of a very important epoch in the history of the "Electrification of the Universe," I have thought for some time that it ought to be in some place where it would be less liable to loss by "fire or theft" than in my own house, and where it would be more easily accessible to any who might be interested in it. If The Franklin Institute cares to become its custodian for the time being, I will be very glad, and it need not be returned to me at present. What is the best place for it finally will be a subject for future consideration.

I am yours faithfully,

(Signed) T. C. MENDENHALL.

DR. R. B. OWENS,
The Franklin Institute,
Philadelphia, Pa.

THE FRANKLIN INSTITUTE AND THE STATE.*

BY

WALTON CLARK, M.E., D.Sc.,

President of the Institute.

THE Institute's purpose, its reason for being, is, within certain well-defined lines, to render service to the State. When we think of the State in this connection we do not confine ourselves to the borders of the great commonwealth which has given us our charter. Our interest and effort are to advance the knowledge of the mechanic arts; to encourage useful research and invention; to aid the struggling worker and reward the worthy worker in the fields of physical science. If in this effort our vision and our influence reach, as we believe, beyond the confines of the city, the commonwealth, and the republic, and beneficially affect the workers of other continents, we are accomplishing in some measure what the founders of the Institute designed and, in their day, realized. The picturesque expression, "splendid isolation," does not apply to The Franklin Institute. While standing alone, secure of its position, and sufficient to the work laid out for it by its founders, it is yet in close and sympathetic touch with the scientific work of the entire world. Through its publication, the JOURNAL, and through the periodic publications of other scientific and governmental bodies of the world, in number over 1500, there is a constant interchange of scientific information on the subjects with which the Institute has to do; and the many stories of invention, discovery, and development that have found their first expression within the walls of the Institute are spread by it as speedily as may be throughout the civilized world.

The Institute is local only to the extent that its habitat is in Philadelphia and the majority of its officers and supporters have been Pennsylvanians. It is cosmopolitan in the range of its interests, its sympathies, and its influence. The scientific world recognizes that for this notable institution, and for the great work it has done for the world in the broad field of science, the citizen of Philadelphia and of the State of Pennsylvania are mainly

* Remarks of Dr. Clark at a joint meeting of scientific and engineering societies of Philadelphia held on the evening of Friday, May 15, 1914.

responsible. Largely because of this work Philadelphia is regarded as in science the leading American city.

The Franklin Institute has to do with the mechanic arts. Does that suggest to any man that we have to do alone with material things?—that the delights of imagination and the glory of an understanding spirit are outside the field of labor of them whom, for the general good, we strive to aid? Believe it not. Let your mental vision range the centuries of invention. Think of Archimedes and DeVinci; of Lippershey and Galileo; of Papin and Watt; of Stevenson and Baldwin; of Daguerre; of Franklin and Faraday; of Morse; of Lavoister and Dalton; of Fulton and Gutenberg and Hoe, and of the hundreds of other discoveries and inventors, self-denying and uplifted servants of their fellowmen, now dead, and of the other hundreds, happily yet living; think of these and believe it not. The tools wherewith have wrought these great workers in Nature's laboratory are of the mind. The application is to the amelioration of man's condition, the broadening of man's understanding, and the extension of man's vision, the refining of man's life and manners—in fewer words, the increasing of man's chance for happiness, through the better adaptation to his use of the substance of the world wherein his Creator has placed him.

To aid in this work, through aiding the worker, The Franklin Institute for the Promotion of the Mechanic Arts was founded. The composition of its membership, provided in its charter and by-laws, evidences the democratic ideals of its founders,—ideals given concrete expression in an Institute in full sympathy with the spirit of American institutions. In the language of the semicentennial address of President Dr. Coleman Sellers, "It is a Democratic learned society." Our membership is open to any well-behaved man or woman. No honest seeker after truth is too humble of birth, or station, or fortune, or attainments to enter and advantage from our work. No man of science is too exalted in rank to accept an invitation to present his facts and theories in the forum of our hall and our journal. You who follow our work know the truth of these statements; and all men must realize how perfectly adapted is an association so organized to serve the individual and State, and that this organization explains the origin of our vitality and its persistence unimpaired to this day, the beginning of the fourth generation.

The Institute offers fruits in evidence that during this long life it has justified the wisdom of its founders, and of its continuing claim to be an institution of utility to the State.

For ninety years Franklin Institute has maintained a school of instruction in the mechanic arts, from which have gone out thousands of young men, and some young women, to a greater usefulness and to greater opportunity and happiness, because of the education and inspiration had at this school. This education has been a factor of importance in the industrial prosperity of the city of Philadelphia; while the school in which it has been had has served as a pioneer and model in the field of vocational training of the young during their earlier years of actual money-earning employment. We are proud of the character of men whom we graduate—a character that supports them through three or more years of work by day and study by night; we are proud of the evidence their subsequent lives have given of the thoroughness and value of our training, and we are very proud of their loyalty. I do not need to tell this to this audience, but I record it here, that it may come to the knowledge of others who are not so familiar with the work of the Institute, and who, perchance, may read these words, if ever they are printed.

During these ninety years the Institute has maintained a lecture course, free to all who would come, and offering opportunity to obtain knowledge of the progress in the mechanic arts at the fountain-head. I am justified in saying "the fountain-head" by the fact that many notable discoveries, inventions, and developments have had their first announcement in the hall of the Institute.

These lectures have been, many of them, by the foremost men in the scientific world, and each of them has been by a man especially qualified to speak on the subject he has presented. Printed in the JOURNAL, these important pronouncements have gone to the scientist, the operator, and the manufacturer throughout the civilized world.

During its earlier years, up to the time of the Civil War, the Institute held yearly exhibitions, which were recognized throughout the country as important and valuable—illustrating to the generation that saw the beginning of the great American industrial development the then state and progress of the mechanic arts. The value of these early exhibitions and of the great later

exhibitions, notably that held on the fiftieth anniversary of the Institute, and the electrical exhibition of 1884, which eclipsed in brilliancy all previous exhibitions of The Franklin Institute, or of any institute, cannot be exaggerated.

The lines of work originated or first described in The Franklin Institute, and now in general use, some under Government direction, are numerous and important. Among them I may mention the Weather Bureau and the Geological Survey.

But it is the continuing work of the Institute that interests me most—the schools and the lectures, of which I have spoken; the meetings of the sections, where gather, through the year, men of all grades of importance in the various industrial arts, to listen to and to discuss lectures delivered by the nation's foremost representatives of progress in these arts; and the work of the Science and Arts Committee, encouraging and rewarding progress, whether in special lines or in the broad, general field of invention and discovery.

Neither Pennsylvania, nor Philadelphia, nor any other political entity, has given to the Institute one dollar or one dollar's worth of securities or of realty. The benefit that the State has had from the Institute's work has been a contribution to the public good by a part of the citizenship—that part whose devotion of money and time has given the Institute its support. The recompense these citizens have received has come from the love of the work and the satisfaction of accomplishment, and it has sufficed. The regret they feel over the neglect of the State to aid in the work has its beginning and its end in the disappointment of the desire to make more useful what is already of service. We who are at the time responsible for the work of The Franklin Institute have no desire to embark in new ventures. The work inaugurated by our predecessors is sufficient in variety and extent for our talents and our time, as we venture to believe it will be found sufficient for the talents and time of our successors. But we have, as they will have, a desire to further serve, by increasing the utility of our laboratories, of our schools, of our libraries, and of our lecture courses, and to extend the work of the Science and Arts Committee. We know not how to better the work of our sections and our committees. We know very well how to increase the value to the State of the service we render. A more commodious building, on a more convenient site, where

more people can use our better disposed library and find room in a larger lecture hall; where the students who now fill our school-rooms will find less crowded space for themselves and for the others who now can find no room; where new laboratories may be to the present-day demand what our present laboratories were to the demands of our industrial yesterday, is the obvious answer to our problem.

Living in the hope of this opportunity for enlarged usefulness, we shall coincidently satisfy our ambition by an earnest effort to continue the work of the Institute in a manner in some measure worthy of the examples of our founders and of the emulation of our successors.

In all this we find our "line of least resistance." We are privileged that it falls in such "pleasant places." Following it, we are proud to know that we serve the State and honor the memory of Benjamin Franklin—scientist.

Decomposition of Rubber by Micro-organisms. N. L. SÖHNGEN and J. G. FOL. (*Zentr. Bakt. u. Parasitenk.*, xl, 87.)—Many bacteria and mould fungi will develop on rubber, in presence of sufficient moisture, at the cost of the protein, sugars, and resins; in some cases red, yellow, black, or brown spots are produced, but the mechanical properties of the rubber are not materially affected. Two species of *Actinomyces, A. elastica* and *A. fuscus,* usually present in garden soil and canal water, are capable of attacking and assimilating the caoutchouc hydrocarbon. This action is due to the developing organisms, not to a soluble enzyme secreted by them, and hence the rubber should be dried as rapidly as possible to prevent bacterial growth.

Behavior of the Wehnelt Electrode in Different Gases. K. FREDENHAGEN. (*Phys. Zeitschr.*, xv, 19.)—It is found that nitrogen lowers the efficiency while the dependence on temperature continues constant. Oxygen also lowers the efficiency very much, and diminishes the dependence on temperature, especially at higher pressures. Hydrogen increases the effect and suppresses the temperature influences almost completely. It appears, according to the results obtained with nitrogen, that the neutral gases lower the effect. An explanation of the results obtained with oxygen is offered. The failure of the temperature influences with hydrogen is difficult to explain and further research in this direction is necessary. Methane and coal-gas behave in a manner similar to hydrogen, while cyanogen acts like oxygen.

Coal Briquettes. ANON. (*Machinery*, xl, No. 16, 682.)—A total of about 181,859 net tons of coal briquettes were manufactured in 1913, according to a bulletin of the United States Geological Survey. The figures for 1913 show a decrease of 17 per cent. in the tonnage produced, but an increase of 5½ per cent. in value compared with 1912. Seventeen briquetting plants were in operation during the year—eight in the Eastern States, five in the Central States and four on the Pacific coast. Seven used anthracite culm or "fines," five used bituminous or semi-bituminous coal, two used carbon residue from oil-gas works, and the others used mixed coals. Coal-tar pitch is the principal binder employed, eight plants use it. Five plants used patented binders.

Atomic Structure. J. J. THOMSON. (*Phil. Mag.*, xxvi, 1044.)—In his recent paper the author supposed that the regions within which the electrical forces inside the atom were supposed to be confined were bounded by conical surfaces. Further investigation shows that the period of a corpuscle inside the region would increase with its energy, and the corpuscle would cease to be in unison with the light before it had acquired enough energy to escape from the region of electrical force. If, however, the boundaries were cylindrical, the period would be independent of the kinetic energy of the corpuscle. The latter would then be in resonance with the light until it had acquired enough energy to escape. Assuming cylindrical surfaces, the results of the paper can apply without further modification.

Band Spectrum of Aluminum. A. DE GRAMONT. (*Comptes Rendus*, clvii, 1364.)—Observations were made of the spectra obtained by introducing metallic aluminum and various aluminum compounds into the high-temperature oxy-acetylene flame. In addition to the five bands already known, a sixth was found, more refrangible than the others. The wave lengths of the heads of the secondary bands in this new band, which is much weaker than the other five, are: 4330.5, 4351.7, 4373.6, 4394.4, 4413.3, 4431.0, 4407.6, and 4462.5. All the bands are degraded, like the others, towards the red, and the first head is not the most intense. A large number of minerals investigated exhibited the aluminum band spectrum.

Graphite as a Lubricant. ANON. (*Amer. Mach.*, xl, No. 22, 938.)—Experiments conducted by Prof. F. W. F. Goss led to the conclusion that a combination of graphite and lard oil makes up a lubricating mixture which, when applied to ball-bearings, will accomplish everything which lard and oil will do, and which, at the same time, will give a lower frictional resistance of the bearings and permit a large increase in the load which they can carry. An oil or light kerosene, when mixed with graphite, becomes an effective lubricant for ball-bearings when operated under light or medium pressure.

THE ENGINEER AS A FACTOR IN MODERN PROGRESS.*

BY

ALEX. C. HUMPHREYS, M.E., Sc.D., LL.D.,

President, Stevens Institute of Technology.
Member of the Institute.

In speaking briefly to this topic which has been assigned to me I am not unmindful of the fact that I am speaking to the members of many societies the membership of which is made up of men of other professions than of my own—engineering.

I have no sympathy with the man who tries to prove that his profession is *the* profession with regard to service to mankind. But I do sympathize with the man who demands for his profession proper recognition in view of its responsibilities and the fidelity and thoroughness with which the members of the profession live up to their responsibilities.

I do not believe that there is a general appreciation of the engineer's part in the world's work; of how his activities permeate practically every branch of the daily round.

When we call attention to details we are able to show that the engineer puts his mark upon nearly everything material which enters into our life. Wherever we see developed power, machinery, manufactures of all kinds, instruments, apparatus—yes, and articles of food—the engineer's work or influence can be found.

This being the case—and I wish I had time to enlarge on this proposition—it means that the engineer has necessarily to accept a heavy responsibility to maintain and increase the efficiency of the world's operations.

I hold that he must carry a heavy responsibility with regard to governmental problems, and particularly so in this country, which is to-day hysterically active in proposing and trying to solve a multitude of problems, the majority of them involving, directly or indirectly, the industrial questions which the engineer should be qualified to solve.

Let me refer to one line among many.

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* Read at a joint meeting of the scientific and engineering societies of Philadelphia held Friday, May 15, 1914.

The engineer should be authoritatively employed in the regulation of our public utilities through the public service commissions, as he is now employed in the management of these public utilities.

It is not an adequate defence for the engineer to say that he has not been called by the voters and their representatives to take a place on the commissions except as a subordinate or member of the staff. The engineer must do his full share to convince the public that this work of regulation and control must not be left to the lawyers, and particularly to the lawyer-politicians. I am not reflecting on the lawyers, but I hold that there is room on these commissions for the engineer, the lawyer, the business man, and the members of all the professions, provided the individuals have good common-sense, common honesty, broad education, including practical experience in administration.

I certainly do not claim that an engineer is qualified to serve acceptably on one of these commissions only because he is an engineer. This applies equally, and perhaps more so, to the lawyer and others.

Judge Prouty, formerly chairman of the Interstate Commerce Commission and now head of the U. S. Board to value the railroads, has recently delivered a strong statement to the effect that, while he did not think so in the past, his experience leads him now to think that the engineer is better qualified temperamentally and by training to serve acceptably on these public service commissions than is the lawyer. To show that the engineers must assert themselves in this connection let me say by way of illustration that only to-day I heard the head of one of our greatest universities (a broad-minded and well-equipped man) state that it is generally understood and accepted that the engineer is not qualified to serve in such administrative positions, but his abilities have to be employed in subordinate and advisory capacities.

Unfortunately engineers have themselves given occasion for this opinion through their failure not infrequently to accept responsibility for the business, economic, and administrative features of the problems put before them. Also, the engineers who have been appointed to such positions have sometimes been the incompetents looking for a job. The engineer to place in such a position of grave responsibility should be a man who has made good—a man of constructive criticism, not of destructive criticism.

We of the United States to-day are suffering from the destructive criticism of those who are incompetent to improve the conditions at which they are so ready to rail and to the reform of which they are willing to devote themselves at so much per hour, week, month, or year.

I am sorry to say that I am convinced (for I am not speaking hastily or rashly) that the college man, the professional men of the country, and especially the economists, are particularly to blame for our present conditions—conditions which I fear are to be worse before they are better.

The so-called educated men—meaning the man of school, college, and books—is to blame far more than the less-favored man if he by his ill-considered words leads others astray.

Particularly is this true of the teacher and professor. The State of Wisconsin has been particularly active in reform movements. Undoubtedly not a little good has been accomplished. But under the academic influence of the State University mistakes have been made.

We now read of organized protests by citizens in various parts of the State against the paternal policies of late so much in evidence in that State. This protest is not directed against public service commissions alone.

I quote from resolutions passed at the organization of the Taxpayers' League of Grant County: "We realize that good may be done in certain lines by commissions of *experienced men properly restricted in their powers,* but we condemn the useless multiplication of commissions to supervise and control every public and private act at the expense of the taxpayers of the State; we condemn the great increase in the cost of commission administration and the employment of hordes of useless employees at public expense. . . . The present conditions in the State of Wisconsin require immediate action for the protection of its people in their rights and property."

Things specified in the protest are: "The great mass of freak and useless legislation"; multiplication of laws; long and expensive legislative sessions; "tremendous indebtedness, and handling of State government by professional politicians."

At the bottom of these protests, bearing every evidence of sincere and honest indignation, lie the growing tax burdens, which in Wisconsin, as elsewhere, are pressing upon the people

as never before in this country during times free from war and its immediate effects.

So long as public utilities and other industries are in private hands responsibility is definitely lodged and those accountable for their activities can be reached and held responsible. When the government assumes the functions of proprietorship, the whole relation to the public changes: transactions of all kinds are confused in the record, and the administration develops into the mysterious fetters of officialdom.

In the same paper from which I have abstracted these statements appears an article by President Van Hise, of the Wisconsin University. Certainly President Van Hise cannot be accused of reactionary tendencies. In fact, he has given evidence of being in sympathy with Wisconsin academic radicalism.

In this article Dr. Van Hise calls for a halt. Particularly he declares against the discrimination against "big business" so much in evidence to-day when the farmers are given freedom to be as big as they please in their combinations. This Van Hise calls a "profoundly immoral situation."

I confess that to get such a warning note from the president of the University of Wisconsin is about as encouraging as anything I have heard of late. Now I am ready for other pleasant surprises.

The legislators are now busy in Washington forging additional fetters for big business, which, properly managed and directed, operates for economy and efficiency.

In this connection let us remember that only a few years ago the States of the Union were almost without exception eagerly competing with each other in offering inducements to corporations to come in and do "big business"; now they are competing with the National Government to sandbag the unhappy victims of their previous legislative activities. Mistakes were made in the past, but if "big business" is to be killed, in fairness the politicians who cultivated and prospered through "big business" should be put out of the way also.

Now why do I say all this to this assemblage? One reason is that it is an unusual opportunity to speak to college men of many professions, and this is the day of college men, engineers and those of other professions, to serve their country, provided

they do not assume, as too many college men do, that the college man is all-sufficient in the working-out of reforms.

I do not think I can do better than conclude by reading an editorial from the *New York Times* of yesterday.

"COLLEGIANS AND CIVICS.

"In his little address to the Conference on Universities and their Relation to Public Service Mayor Mitchell brought out one point that may well be considered carefully by those responsible for the universities. By some of them, indeed, the study of it should be accompanied by fasting and prayer. He reported that in many cases that had come under his observation college men who had entered the public service temporarily, or with the intention to remain, were lacking in the ability to handle their work practically, getting on with it less satisfactorily than young men with fewer and poorer 'advantages' than they. One of the objects which he held out for the consideration of the conference was coöperation to enable men who are in attendance at universities to get a practical knowledge of the workings of government that will fit them to take part in it when they enter business life.

"The suggestion is a pregnant one. In a lamentable degree it is true of the college teaching of civics that the practical side is neglected and undue stress is laid upon the theoretic side. This is not only true, but it is equally so that the theoretic side has too much to do with more or less abstract views as to the reforms that are assumed to be imperative in the organization of our public life. These views relate for the most part to what is called, in the vernacular, not to say the slang, of modern civics the 'uplift' of society with especial regard to social changes. This pabulum is exceedingly stimulating to young minds, and it is by no means without nutritive value properly administered; but it needs, in order to be safe, to be accompanied by a substantial element of practical instruction. For one thing, it is highly expedient that students who are to be trained to reform existing institutions and methods should have an accurate and as nearly complete knowledge of what they are to try to reform as possible.

"If we are to correct evils we must know as nearly as we can the nature and cause of these evils. This means that in training young men and young women in civics we should keep them as close as may be to concrete facts, and restrain them from arriving

too soon at general principles and adopting tempting theories which are usually dangerous in the ratio that they are promising. These restraints are needed first by the minds of the young in their own interest, and, second, in the interest of the public. There is a distinct and peculiar risk in permitting, still more in inducing, the young to think that they have a mission for the bettering of the world before they have attained a knowledge of the world. That conception tends strongly to make them conceited, to transfer to their own credit the goodness of their intentions and to blind them to the truth about themselves and those with whom they have to deal. It puts into their minds much that has afterward to be got out by the stern processes of experience, which are often rude and cruel. In the meantime the public which these young enthusiasts are taught to believe they are serving loses a lot of good hard work which might be done if teaching were more properly adjusted to conditions.

Are we then to abandon the instruction in civics in our universities and banish therefrom the discussion of needed reforms? Certainly not. We must, however, recognize the extreme risks in theoretic teaching unless linked with thorough instruction in the concrete. That is more than a corrective or safeguard against erratic speculation. It is a positive preparation for the world of life, and a discipline in the tasks that await the student. Nor is the process a difficult one. It can be aided by the conference that Mayor Mitchell welcomed to the city and is, we understand, a part of its program. The results may well be beneficial to all concerned, for it is in the field of the concrete that the universities, such as that of Wisconsin, have accomplished most. It is a constantly widening field and may well occupy energies that in the past have been too much devoted to the theoretic."

From a long and instructive experience I say Amen! and Amen! to every word of this editorial.

Splitting of Tiles by Frost. C. RAD. (*Tonind. Zeit.*, xxxviii, 649.)—Glazed tiles with strongly porous edges are split by frost, whereas unglazed tiles made of the same clay are not affected. Glazed bricks are more resistant than glazed tiles. This is due to the greater thickness and less exposed situation of the bricks, through which less water is absorbed, whereas thin, flat roofing tiles become fully saturated.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE EMISSIVITY OF METALS AND OXIDES.—I. NICKEL OXIDE (NiO) IN THE RANGE 600 TO 1300° C.[1]

G. K. Burgess and P. D. Foote.

THE object of the present investigation has been the determination of the monochromatic ($E\lambda$) and total emissivity (E) of nickel oxide (NiO) in the range 600 to 1300° C. This oxide forms in a tough, smooth layer on the surface of nickel when subjected to high temperatures in air. Two methods were employed for the determination of the emissivity for red light: (*a*) that of microscopic melts, and (*b*) a direct comparison by a spectrophotometer of the intensity of light emitted by the glowing NiO and by a black body at the same temperature.

In the method of microscopic melts, minute specimens of NaCl, Na_2SO_4, and $A\mu$ were placed on the oxide, which was electrically heated until these substances melted, as observed with a microscope, and the "apparent" temperatures at the instant of melting were observed with an optical pyrometer. Hence, knowing both the true and apparent temperatures of the oxide, the emissivity may be computed.

In the spectrophotometric method, a nickel strip was folded forming a wedge- or V-shaped cavity and electrically heated until a coat of the oxide was formed. It has been shown by Mendenhall that the radiation from the interior of a V-shaped cavity is "black." The ratio of the intensities of the outside and inside of the wedge properly corrected for temperature gradient through the walls, gives at once the emissivity at any particular wave length and temperature. Determinations by this method agreed with those by the method of microscopic melts.

The monochromatic emissivity was found to increase linearly with increasing wave length from $\lambda = 0.5$ to 0.7μ and decrease linearly with increasing temperature from 700 to 1300° C. For example, at 1160° C., $E\lambda$ increases from 0.86_5 at 0.5μ to 0.88_2 at 0.7μ; and for $\lambda = 0.65\mu$, $E\lambda$ decreases from 0.95_8 at 800° C. to 0.84_5 at 1300° C.

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* Communicated by the Bureau.

[1] Scientific Papers of the Bureau of Standards.

The total radiation of NiO was investigated by means of 12 radiation pyrometers of the Thwing and Fery types. These instruments were sighted upon the electrically heated oxide. The apparent temperature of the oxide for $E\lambda = 0.65\mu$ was measured by an optical pyrometer and these values corrected to true temperatures by means of the determinations on the monochromatic emissivity. From the apparent temperatures as determined by the radiation pyrometers and the true temperatures, the total emissivity may be computed. E was found to increase with increasing temperature, but the relation is not linear. Temperatures and E have respectively values as follows: 600°, 0.54; 800°, 0.68; 1000°, 0.76; 1200°, 0.85; 1300°, 0.87. Tables and curves are given for correcting the apparent temperatures of NiO, observed with an optical or radiation pyrometer, to true temperatures.

[ABSTRACT.]

THE SPECIFIC HEAT OF COPPER IN THE INTERVAL 0° TO 50° C. WITH A NOTE ON VACUUM JACKETED CALORIMETERS.*

D. R. Harper 3d.

1. A CRITICAL review of all previous determinations of the specific heat of copper is given *in extenso*. For the general reader the essentials of this are condensed into two tables and a short explanatory note. The determinations in the temperature range 0 – 100° are interpreted to indicate that the specific heat of copper (hard-drawn probably excepted) at 50° is between 0.0926 and 0.0931.

2. The general principles of the method employed in this determination are discussed, together with a consideration of the precision necessary in measuring the various quantities. Then follow a full description of the apparatus and the details of making each measurement.

The specimen of copper was a long wire (50 metres), suspended in vacuo and connected as part of an electric circuit. A measured quantity of heat could thus be imparted to it electrically and the temperature rise found by using the specimen

* To appear in the Bulletin of the Bureau of Standards, vol. 11, 1914.

itself as a resistance thermometer. The test specimen was thus its own calorimeter, no other substance being included in the "water equivalent" with the single exception of a few grammes of mica necessary for electrical insulation.

To arrange a large enough amount of copper in a form suitable for the electrical measurements, the wire was coiled into spirals containing about 150 cm. each, and 32 of these, superposed with mica plates between, built up a cylinder about 10 cm. x 10 cm. containing over 2 kilogrammes of copper and possessing an electrical resistance of about 0.2 ohm, sufficient to permit of making the necessary measurements with requisite accuracy.

Potential leads tapped in at a distance from the ends of the wire served to define a portion, the mass of which was the mass of copper involved in the determination. The resistance of this portion was that which was comprehended in the thermometric factor, and the energy supplied to it during the period of heating was the product of the current in the coil by the potential drop between these leads, integrated over the time the heating circuit was closed. This potential drop was measured directly with a potentiometer and the current was measured with the same potentiometer balanced on the drop across a 0.1 ohm resistance standard connected in series in the circuit. The time factor was obtained by automatic chronograph record of the instants when the heating current was switched on and off.

The specimen was heated 4° to 5° in each experiment, the rise in temperature being determined by the change of resistance of the specimen relative to the resistance of a 0.1 ohm manganin resistance standard immersed in an oil bath. The comparison was effected by a potentiometer, sensitive to about one part in five hundred thousand, and the current employed in making the comparison was small enough (about 0.3 ampère) that its heating effect on the specimen (about 0°.001 per minute) could readily be allowed for without appreciable error.

To obtain the factor for the reduction of the increase in resistance to rise of temperature on the international hydrogen scale, the copper thermometer was compared at several temperatures with two standard platinum thermometers in a suitable stirred oil bath comparator.

By suspending the specimen in vacuo, the uncertainties in the cooling correction which occur at atmospheric pressure due to con-

vection were avoided, the magnitude of the correction was decreased, and uncertainty in amount of air to be included in the water-equivalent (a source of error barely appreciable) was avoided. The efficacy of the vacuum jacket in reducing the magnitude of the cooling correction was by no means what was anticipated and is the occasion of an appended note on the subject.

3. Sources of possible error are carefully considered in the separate discussions pertaining to the measurement of each quantity. The precision of these measurements and the magnitudes of the several correction terms are fully indicated by detailed explanation accompanying a sample laboratory record of an experiment.

4. The copper was annealed wire, 99.87 per cent. pure, according to chemical analysis, high degree of purity being likewise indicated by the electrical properties.

5. The results of 27 determinations at temperatures between 15° and 50° possess an average deviation of one part in a thousand from

$0.3834 + 0.00020(t-25)$ international joules per gramme degree

equivalent to

$0.0917 + 0.000048\ (t-25)$ calories_{20} per gramme degree

$\frac{1}{2}$ 4.182 joules equal one 20° calorie.

6. Appended to the paper is a discussion of the use of the vacuum jacket as a means of reducing the cooling correction in calorimetry, the relative magnitudes of the heat transfer due to conduction by air in various stages of rarefaction and by radiation from some of the more commonly used surfaces being compared. The note is intended to indicate the degree of exhaustion profitable to attain for a given set of fixed radiation conditions when thermal insulation by means of a vacuum jacket is planned.

THE VERITAS FIRING RINGS.*

A. V. Bleininger and G. H. Brown.

IN the pottery and other clay industries the heat effect due to the increasing kiln temperature is frequently determined from the shrinkage of unburned clay rings, of uniform composition and

* Technologic Papers of the Bureau of Standards, No. 40.

size, which are placed in different parts of the kiln. The shrinkage is measured by means of a simple calipering device which permits the reading of small differences in diameter. The object of the present work was the correlation of the arbitrary shrinkage number of the gauge with temperature as measured by means of standardized thermo-couples, so that the devices might be coördinated with pyrometer practice.

The work consisted in firing a number of these rings under conditions of constant temperature increase per unit time. Four firings were made with increases in temperature of 50, 25, 16.66 and 12.5° C. per hour. At frequent intervals rings were withdrawn from the kiln and their diameter measured after cooling. The results showing the shrinkage, expressed both in the numbers indicated by the gauge and in fractions of an inch (obtained by micrometer measurement), are given in tables. The temperature at which equal contraction takes place are the higher the more rapid the firing. The differences diminish as the temperature rises. The shrinkages for the two lower firing rates tend to coincide as the heat absorption becomes constant. Porosity determinations were made in connection with the shrinkage measurements and which resulted in curves practically parallel to the linear contraction. The firing rings were found to answer the purpose for which they are intended satisfactorily. A new series of rings, intended for lower temperatures, was found to be unsatisfactory, owing to irregularities in shrinkage.

Passenger Locomotives. ANON. (*Machinery,* xx, No. 8, 650.)—It is stated in the *Railway Age Gazette* that a great increase in the capacity of passenger locomotives has been effected by the use of alloy steel, properly heat-treated, for the reciprocating parts. This material considerably reduces the weight of the counterbalances, and thus allows an increased load to be applied to the driving wheels. Hence the boiler can be materially enlarged and the capacity of the locomotive as a whole increased without adding to the total weight.

Mastic Lining for Acid Tanks. ANON. (*Min. and Eng. World,* March 28, 1914.)—Trinidad asphalt mastic has been found to be a satisfactory material for lining concrete tanks which are subjected to the action of sulphuric acid. Many other materials were tried but none were found suitable except the asphalt mastic, which showed no deterioration after a year's test.

Determination of Mineral and Rock Densities at High Temperatures. A. L. DAY, R. B. SOSMAN, and J. C. HOSTETTER. (*Amer. Journ. Sci.*, xxxvii, 1.)—After reviewing existing and somewhat conflicting data on the change of volume on fusion of various rocks, the authors describe apparatus by which the volume of metals and of solid and liquid silicates can be determined from 250° C. to 1600° C. The sensitiveness of the method is from 0.03 to 0.2 per cent. The accuracy varies with the metal used, the temperature, and the size of the sample, but is usually between 0.2 and 0.5 per cent. The fundamental constant is the expansion coefficient of artificial graphite. Volume measurements on quartz up to 1600° C. show a dilatation which increases rapidly as the inversion point of 575° C. is approached. Above this temperature quartz contracts slightly. At about 1300° C. there begins a second and irreversible dilatation due to the formation of cristobalite. Owing to the unequal expansion of the various minerals the rock is fractured, so that the true volume-change over any considerable range cannot be obtained from natural rocks.

Electrolysis of Barium Chloride Solutions with Mercury Cathodes. P. P. FEDOTIEFF. (*Z. Anorg. Chem.*, lxxxvi, 325.)—The Kellner-Solvay method may be applied with good results to the preparation of pure barium oxide from barium chloride solution, a given current yield being obtained with smaller cathode density than with the alkali chlorides, owing to the relative stability of barium amalgam. The amalgam is, however, rapidly decomposed by water at 60° C. in the presence of iron, and a solution which, on cooling, deposits crystals of $Ba(OH)_2$, $8H_2O$, is readily prepared. Castner's method is less suitable. An increased cathode density is favorable to a high current yield.

Moving Pictures in the Machine Industry. ANON. (*Amer. Mach.*, xl, No. 16, 676.)—The use of moving pictures in the publicity field of the machine industry is not new, but is becoming extended. One firm, in Hull, England, making oil-mill and other machinery for export, has a "private picture palace" for showing its machinery in operation under various circumstances. This device is found particularly valuable in entertaining foreign customers who want to see how the machinery is employed in actual practice. It is more simple, and really more effective, to show the moving pictures than to show the customers through the mills, even when such a course is possible. It obviates the often unpleasant necessity for asking the permission of customers who had bought the machinery to show prospective customers through their mills. An important variation of the scheme is to send the films abroad, with or without a salesman, for the benefit of customers who might never have an opportunity to see the actual operation of the machinery in other countries.

THOMAS DOLAN

THE FRANKLIN INSTITUTE

MEMBERSHIP NOTES.

NECROLOGY.

Thomas Dolan was born on October 27th, 1834, and died June 12th, 1914. He lived his entire life in Philadelphia and his activities were mainly with those connected with Philadelphia.

As a manufacturer, financier, as President of the United Gas Improvement Company, and as director and adviser of many industries, his many qualities so impressed themselves on these various interests, that he was the leader in each field.

His genial nature, approachable manner and sympathetic interest, at all times, were traits that impressed all who came in contact with him.

He was the pioneer in impressing on those who had reason to use the facilities offered by the various public utility companies, that the desire of these companies was to have their relations on a human basis.

With the great attainments in so many fields possessed by Mr. Dolan, it is somewhat difficult to select the one which seems the most enduring; but all who know of his work will agree that one of the greatest of his achievements was in establishing that community of interest between the user and supplier of so-called Public Utilities, so that to-day the suspicions and ill feelings of the past have changed to a condition of mutual confidence and respect.

Mr. Dolan was identified with many institutions. He was a member of The Franklin Institute for many years, and an earnest, sympathetic believer in its aims and its future, he being one of the subscribers to the Building Fund.

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Denatured Alcohol. ANON. (*Machinery,* xl, No. 16, 682.)—According to a monograph recently issued by the Bureau of Foreign and Domestic Commerce, Germany now uses between 40 and 50 million gallons of denatured alcohol per year, of which over 30 million gallons are sold to the general public for fuel purposes. The importance of this fuel in Germany may be appreciated when it is considered that France uses about 18 million gallons, the United States about 10 million gallons, and the United Kingdom only 4 million gallons. Denatured alcohol is not only gaining in favor for general burning purposes, but a determined effort is being made to find a method of using it as a motor fuel in place of high-priced gasoline.

The American Peat Society will hold its eighth annual meeting in Duluth, Minn., August 20th, 21st, and 22nd.

Important papers on the peat industry, peat lands, and the use of peat for fuel will be presented by numerous investigators and experts from this country and abroad.

The meetings will be held in the rooms of the Commercial Club, where there will also be an exhibition of peat, peat products, and machinery and apparatus for its preparation and development. The program will include excursions and entertainments.

About 4000 **vanadium-steel reaction castings** were used for the locks of the Panama Canal at Gatun and Miraflores. In planing these the cutting speed was 40 feet per minute; the time required for the lot was 1½ years, working day and night except Sundays. The strain on the planer was so severe that all the gears and racks had to be replaced by steel ones.

CURRENT TOPICS

Recovery of Nitrogen as Ammonia from Coal. J. W. COBB. (*J. Gas Lighting,* cxxvi, 329.)—The experiments of Burgess and Wheeler on the slow distillation of bituminous coal in a vacuum showed that the greatest yield of ammonia per gramme of coal was obtained at about 550° C. Christie noticed that very little ammonia was produced below 500° C. or above 800° C., and that by slow distillation at 500° C. to 700° C. about twice as much ammonia could be obtained as in the usual coke-oven or gas-retort practice. At 700° C., when equilibrium is attained, a mixture of nitrogen, hydrogen, and ammonia at atmospheric pressure contains only 0.022 per cent. NH_3, and a gas consisting of H_2 50, N_2 5 and NH_3 1.2 per cent., if left in contact with the charge in the retort at 800° C. would lose practically all of the ammonia by decomposition. Hence it is necessary to produce the ammonia at the lowest possible temperature and to remove it from the retort as soon as formed. In laboratory experiments at 800° C., when the gas was removed at once from the hot part of the tube, 22.5 per cent. of the nitrogen in the coal was obtained as ammonia; when the gas passed through a red-hot portion of the tube before exit, 17.2 per cent.; and when the gas passed through red-hot coke, 9.4 per cent. When a current of carbon monoxide, carbon dioxide, or nitrogen was passed over coke at 800° C., little or no ammonia was obtained from the nitrogen in the coke; with dry hydrogen, 10 per cent. of the nitrogen was liberated as ammonia; and when water vapor, alone or mixed with hydrogen, was used, nearly the whole of the nitrogen was obtained as ammonia. The conditions approximate this in the Mond producer, in which 60–70 per cent. of the nitrogen is recovered. Producer gas or coke-oven gas which has been well scrubbed for the extraction of ammonia is specially suitable for regenerative working on a continuous system without reversals, because it is free from dust and does not choke the narrow conduits.

History of the Zeppelin Airship. MÜLLER. (*Verein zu Beförd. des Gewerbfleisses,* Verh. 1, 35.)—First are recalled the difficulties encountered by Zeppelin when, in 1894, a German Committee was appointed to consider the military value of his first rigid airship proposals. The present communication is claimed to rectify serious omissions from "Das Werk Zeppelin's," a history compiled in honor of the inventor's 75th birthday. Working on the basis of experience obtained with the 1884–1885 French military airship "La France," defects and limitations were detected in the 1894 Zeppelin ship, and the author gives a connected account of the investigations and cal-

culations which were made; the difficulties encountered owing to the very different shapes of the old and the new crafts; the modifications which were made in the design and dimensions of the Zeppelin ship; and the factors which opposed the realization of conditions seen to be desirable. Numerous formulæ for speed and resistance, etc., are presented, and their applicability and results discussed. The leading dimensions of the "Deutschland" and "La France" are given. Great difficulty was encountered in securing sufficient strength of the hull framework while keeping the total weight sufficiently low; the engines available at that date were relatively heavy and of limited power, hence only low speeds could be attained. Those considerations are clearly set forth which led to the result that very large vessels should be built in order to make possible safe construction while realizing high speed. Lifting power and with it the possibility of strong construction and powerful engines, increases with the third power, whereas air resistance increases only with the second power of the linear dimensions. The difficulty of making the hull strong enough to withstand mooring in the open was realized at an early date. The shape of the hull affects not only air-resistance but also the weight of the framework. Tables are given, showing the length, diameter, capacity, motor horse-power, and speed of Zeppelins I to XIX; LZ-1 to 6 inclusive conformed closely to the formula: Speed (in m./sec. $= \sqrt[3]{2000\, n/d^2}$; where n = horse-power and d = diameter; the length of the ships ranging from 128 to 136 metres; their capacity from 11,300 to 15,000 cubic metres; their engine power from 30 to 230 horse-power; and their speeds 7.5 to 13m./sec. The later craft conformed to $v = \sqrt[3]{4000\, n/d^2}$; their length ranging from 140 to 158 metres; their capacity from 17,500 to 22,465 cubic metres; their engine power from 450 to 510 horse-power, and their speed from 19.3 to 22.2 m./sec. The chief factor which delayed for so long the development of the Zeppelin ships was the weight and limited power of the engines available.

Year	Motor	Horse-power	R. P. M.	Kg. per H. P.	Fuel per H. P. hour
1892 (projected)	Daimler	11	440	45.0	500 Gm.
1899	.....	15	680	25.7	400 Gm.
1905	.....	90	1050	4.07	625 Gm.
1907	.....	100	1080	3.4	to
1909	.....	115	1100	3.2	240 Gm.
1910	.....	120	1100	3.2	225 Gm.
1910	Maybach	145	1100	3.1	240 Gm.
1913	.....	180	1200	2.55	225 Gm.

Radio Research Laboratory for Bureau of Standards. ANON. (*Electr. World*, lxiii, No. 13, 684.)—The Department of Commerce has asked Congress for an appropriation of $50,000 for the es-

tablishment of a wireless-telegraphy research laboratory in connection with the Bureau of Standards at Washington. It is planned to locate the laboratory in the recently completed electrical building of the Bureau of Standards, and the tower for the antennæ will be erected on the east side of the structure. It is proposed to build the tower of masonry in order to preserve the unity of the architecture of the group of buildings.

Artificial Silk Manufacturing Results. ANON. (*Chem. Trade J.*, April 14, 1914.)—The viscose process for the manufacture of artificial silk is making rapid progress among Continental manufacturers, and the financial results of two important concerns that have discarded other processes in favor of the viscose process are sufficient to show that the change has not been made at the expense of the profits. The Fabrique de Soie Artificielle de Tubize, which has hitherto manufactured by the gun-cotton process, is increasing its capital by two million francs to acquire a controlling interest in a new company which will work the viscose system in Belgium. The last report shows a net profit of 1,088,902 francs, and dividends of 25 per cent. on the preference shares and 20 per cent. on the ordinary shares are being paid. The report issued by the Vereinigte Glanzstoff-Fabriken, Elberfeld, probably the largest producers of artificial silk in the world, shows a net profit of 5,743,598 marks, against 3,726,825 marks in the previous year, and a dividend of 34 per cent. is proposed. Up to about two years ago this company worked only the cupro-ammonium process, but it has since adopted the viscose process with good results.

Revision of Road Board Specifications for Tar. ANON. (*J. Gas-Lighting*, cxxv, 807.)—The chief modifications of the earlier specifications are as follows:—*Tar No. 1* (*for surface tarring of roads*): The requirement that the distillate between 170° C. and 270° C. shall remain clear and free from crystals of naphthalene, etc., when kept at 30° C. for half-an-hour, may be waived in the case of tar supplied direct from gas works, but it is preferable not to use tar containing much naphthalene. The tar should contain from 12 to 21 per cent. of "free carbon" (*i.e.*, residue left after extraction with benzene and carbon bisulphide). *Tar No. 2* (*for making tar-macadam and for surface tarring in very hot weather when the road-crust is exceptionally dry*): The tar should contain from 12 to 22 per cent. of "free carbon" and may contain up to 25 per cent. by volume of tar (or distillates or pitch therefrom) produced in the manufacture of carburetted water-gas. *Pitch and tar oils.* Prepared pitch from tar distilleries should contain 16 to 28 per cent. and commercial soft pitch 18 to 31 per cent. of "free carbon." The soft pitch and tar oils may contain up to 25 per cent. of products from carburetted water-gas tar.

The Measurement of the Radioactivity of Springs. C. ENGLER, H. SIEVEKING and A. KOENIG. (*Chem. Zeit.*, xxxviii, 425.)—An improved form of the Engler and Sieveking fontactoscope is described, by which more exact measurements of the radioactivity of natural waters may be made. It consists of a vessel of 10 litres capacity, on the neck of which fits a hollow conical stopper, supporting a Wulf quartz-fibre electrometer. Through a hole in the stopper, which can be closed at will by a rubber plug, passes a conducting wire connecting the electroscope with a rod suspended within the large vessel. Before use the normal rate of discharge is determined by shaking in the vessel, for half a minute, one litre of inactive distilled water, charging the electroscope, and observing the fall of potential, which under normal conditions should be between 15 and 30 volts per hour. One litre of the active water is then shaken in the vessel for half a minute, whereby all except about 2 per cent. of the radium emanation is transferred to the air. The fall of potential per hour is again determined, the normal loss deducted, and a correction applied for the solubility of the emanation in the water, and for the Duane effect; *i.e.*, the size and form of the apparatus. From the fall of potential per litre per hour thus calculated, the activity of the water is given by

$$A = \frac{V}{300} \times \frac{C}{3600} \times 1000$$

Mache units, where V = fall of potential and C = capacity of system. The results to be of comparative value must be referred to some definite time from the commencement of the shaking out of the emanation, as the activity, due to the pure emanation, rapidly increases owing to the production of *RaA* and *RaC*. In making rapid measurements the readings should be taken two minutes from the commencement of the shaking out, and tables are given to enable such figures to be referred to the zero time; *i.e.*, the activity of the pure emanation.

Gardner's Gyroscope. ANON. (*Engineering*, xcvii, 229.)—Describes the specially free running gyroscope for use in steering a torpedo. It may be spun by a jet of compressed air directed on to buckets in its periphery. With an initial speed of 4000 revolutions per minute the total run may last about 35 minutes, the diameter is 3 inches and the mass 2 pounds.

Flameway in Boilers. ANON. (*Amer. Mach.*, xl, No. 8, 759.)—The aim of boiler designers is to obtain the greatest number of pounds of steam to each pound of metal in the boiler. Various studies and experiments have clearly indicated the advantage of the use of a longer flameway between the fuel bed and the end of the tubes, giving an opportunity of completing the gaseous reaction before the products of combustion enter the flues.

Powerful Röntgen-ray Tube with a Pure Electron Discharge. W. D. COOLIDGE. (*Phys. Rev.*, 2 Ser. 2, 409.)—A new and powerful Röntgen-ray tube is herein described in detail. It differs in principle from the ordinary type in that the discharge current is purely thermionic in character. Both the tube and the electrodes are as thoroughly freed from gas as possible, and all the characteristics seem to indicate that positive ions play no appreciable rôle. The pressure is as low as it has been possible to make it; *i.e.*, not more than a few hundredths of a micron (*i.e.*, a few hundred-thousandths of a mm.), instead of as in the ordinary tube a few microns (thousandths of a mm.). The kathode consists of a body which can be electrically heated (such as a tungsten or tantalum filament) and, suitably located with reference to this portion, an electrically conducting ring or cylinder, consisting preferably of molybdenum or tungsten or other refractory metal. The ring or cylinder is connected either to the heated portion of the kathode or to an external source of current, by means of which its potential may be brought to any desired value with respect to the heated portion. The heated portion of the kathode serves as the source of electrons while the ring or cylinder assists in so shaping the electrical field in the neighborhood of the kathode that the desired degree of focussing of the kathode-ray stream upon the target shall result. The anti-kathode, or target, functions at the same time as an anode. The tube allows current to pass in only one direction and can therefore be operated from either direct or alternating current. The intensity and the penetrating power of the Röntgen rays produced are both under the complete control of the operator, and each can be instantly increased or decreased independently of the other. The tube in operation shows no fluorescence of the glass and no local heating of the anterior hemisphere. The starting and running voltage are the same.

Explosion of Acetylene from Calcium Cyanamide in Trieste Harbor. G. MORPURGO. (*Mitt. K. K. T. Techn. Versuchsamtes*, iii, 60.)—This is a report on a violent explosion which occurred last January on a ship having on board 600 sacks of calcium cyanamide. Eight samples of the calcium cyanamide yielded on treatment with water, acetylene corresponding to from 1.28 to 9.35 per cent. of calcium carbide. The hold in which the sacks were stored was only half-full and was not ventilated, and the explosion was evidently due to the liberation of acetylene from the carbide present in the calcium cyanamide by the action of moisture. It has been ordered that in future, calcium cyanamide must always be packed in iron drums for transportation. The author has found that if jute sacks which have been impregnated with rosin solution be used and filled while still damp, the rosin solution combines with the calcium cyanamide with which it comes in contact, and forms a perfectly water-tight coating.

Embrittling of Iron by Sodium Hydroxide. J. H. ANDREW. (*Trans. Faraday Soc.*, March, 1914.)—Wrought iron corrodes slowly, becomes highly crystalline, and eventually brittle by immersion in a concentrated aqueous solution of sodium hydroxide at 100° C. for several months. The corrosion is attributed to electrolytic action between the two phases, crystalline and amorphous, of which the metal is constituted, iron going into solution at the anode (forming sodium ferrite), hydrogen being liberated at the cathode. Part of the hydrogen is occluded by the metal, being first absorbed by the amorphous constituent, thereby forcing the crystals apart, and ultimately causing the iron to become crystalline and brittle. The brittleness decreases with time, an equilibrium being finally established between the metal and the gas, and is due rather to the molecular rearrangement induced by mere occlusion or evolution of hydrogen than to the mere presence of the latter in solution. The potential difference between the amorphous and crystalline phases and hence the rate of corrosion decrease as the latter phase becomes hydrogenized, the passivity of iron produced by immersion in caustic soda being due to this cause. Similar results were obtained with electro-deposited iron, but steel containing 0.5 per cent. carbon was much less affected by sodium hydroxide solution. The recrystallization of electro-deposited iron upon cooling through the Ar_3 point is also considered to be due to the evolution of hydrogen.

Ignition of Gaseous Mixtures by the Electric Discharge. H. F. COWARD, C. COOPER, and J. JACOBS. (*Chem. Soc. Trans.*, CV, 1069.)—The inflammability of various gaseous mixtures was compared by determining the lowest pressures at which the mixtures could be ignited with a given sparking arrangement. Mixtures of oxygen and hydrogen were more inflammable as the proportion of oxygen was increased up to 70 per cent. Electrolytic gas at a pressure somewhat too low for ignition became inflammable by adding, without change of volume, either oxygen, hydrogen, nitrogen, carbon dioxide, or argon. Experiments were also made with mixtures of oxygen with carbon monoxide, cyanogen, methane, and ethylene respectively, and with various diluents in each case. Two important factors governing the ignition were the thermal conductivity of the mixture and the energy degraded when the spark was passed; in the case of the mixtures of moist carbon monoxide with oxygen and diluents, a third important factor was the "activation" of oxygen by the discharge.

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